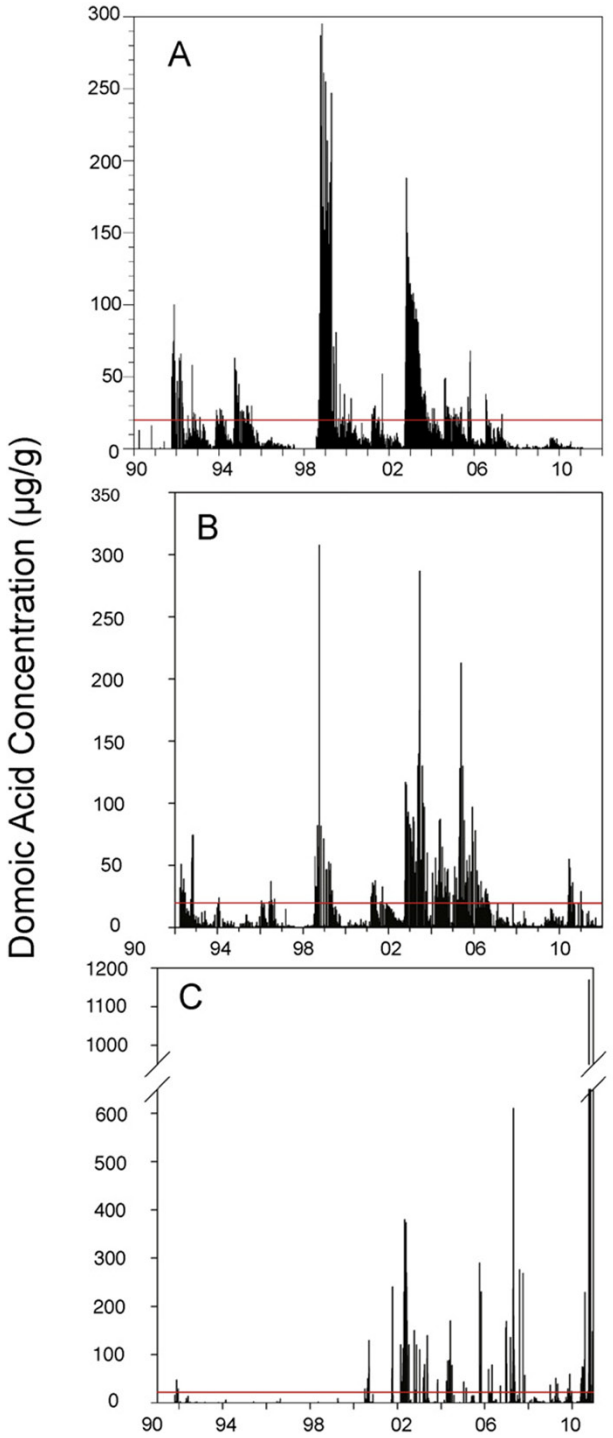
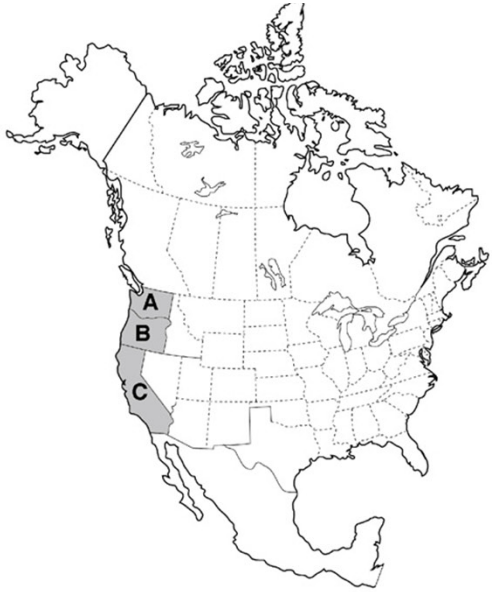
Phytoplankton-Nutrient Interactions

Raphael Kudela
University of California Santa Cruz



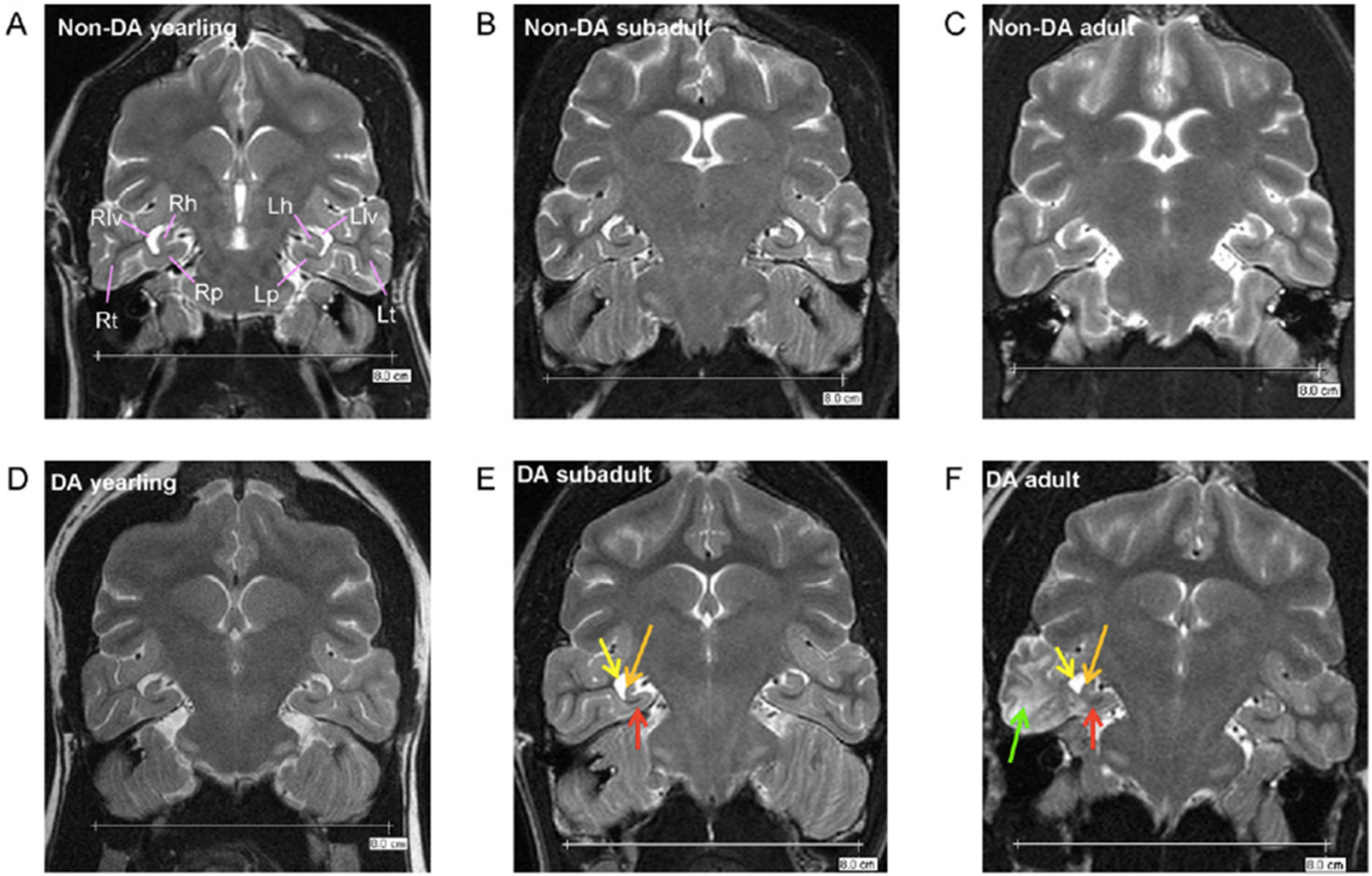


Pseudo-nitzschia spp.

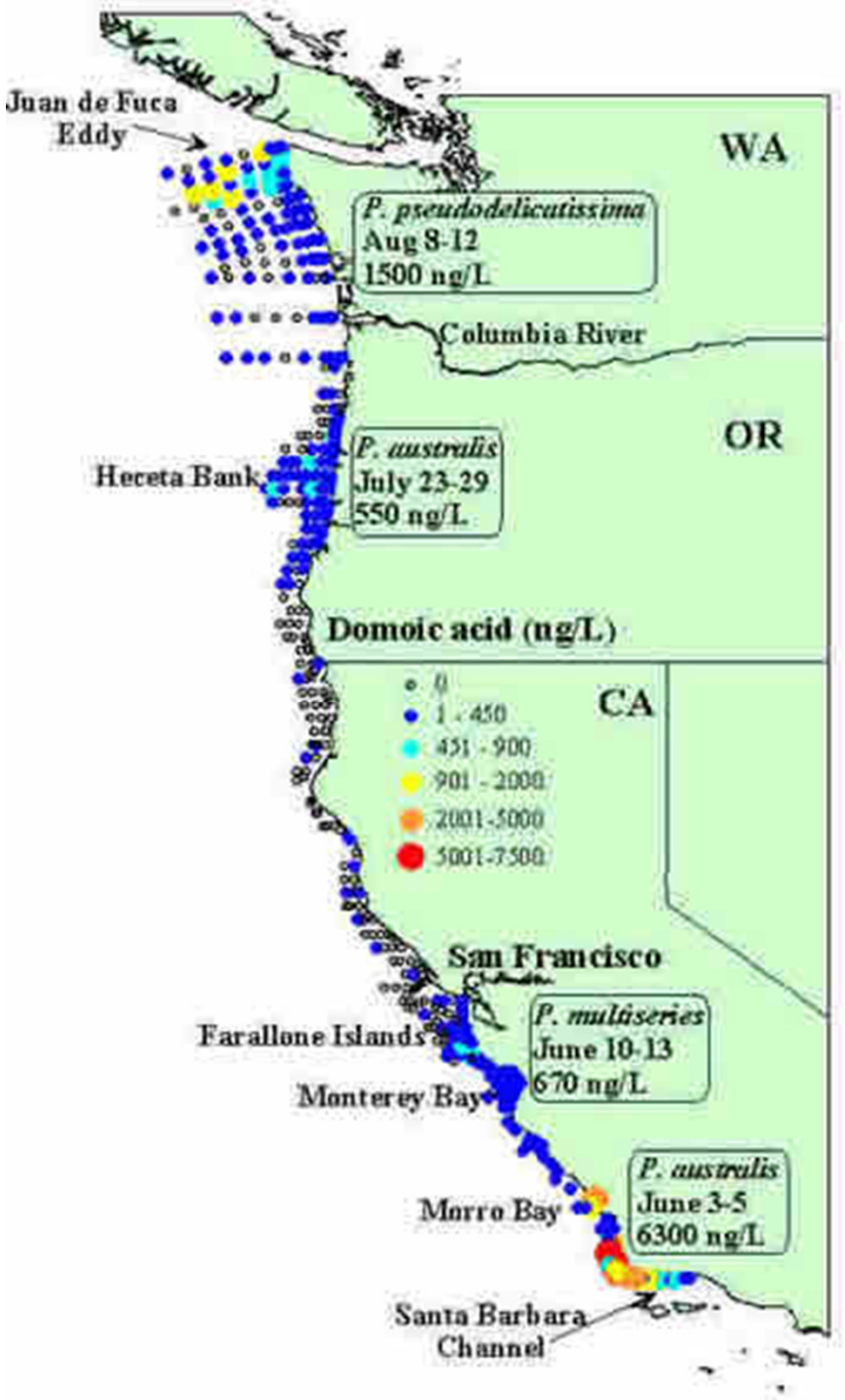
- Cosmopolitan
- Causes Amnesic Shellfish Poisoning
- Water-soluble toxin (domoic acid) over-stimulates the nervous system
- Originally used in Japan as a dewormer, classified as an HAB 1991

Lewitus et al. 2012, Harmful Algae

Chronic Exposure to DA in Sea Lions causes permanent damage, ongoing micro-seizures (potentially in humans also)



Montie et al. *Harmful Algae* 2012



1998 West Coast Survey

Identified "Hotspots"

- Juan de Fuca Eddy
- Heceta Bank
- Monterey Bay
- Santa Barbara Channel
- Southern California Bight

Combination of physically retentive with a supply of nutrients…

Razor clam season closes early after high domoic acid levels found

BY JEFFREY P. MAYOR
Staff writer May 13, 2015

Domoic acid poisoning alert along Washington, Oregon coastline

BY KAREN GRAHAM MAY 10, 2015 IN FOOD

Oregon and Washington state health officials issued a warning on Friday asking recreational and commercial diggers of razor clams taken from selected beaches on Thursday and Friday to be destroyed due to high levels of the marine toxin, domoic acid.

Mussel-collecting ban expanded on Oregon Coast

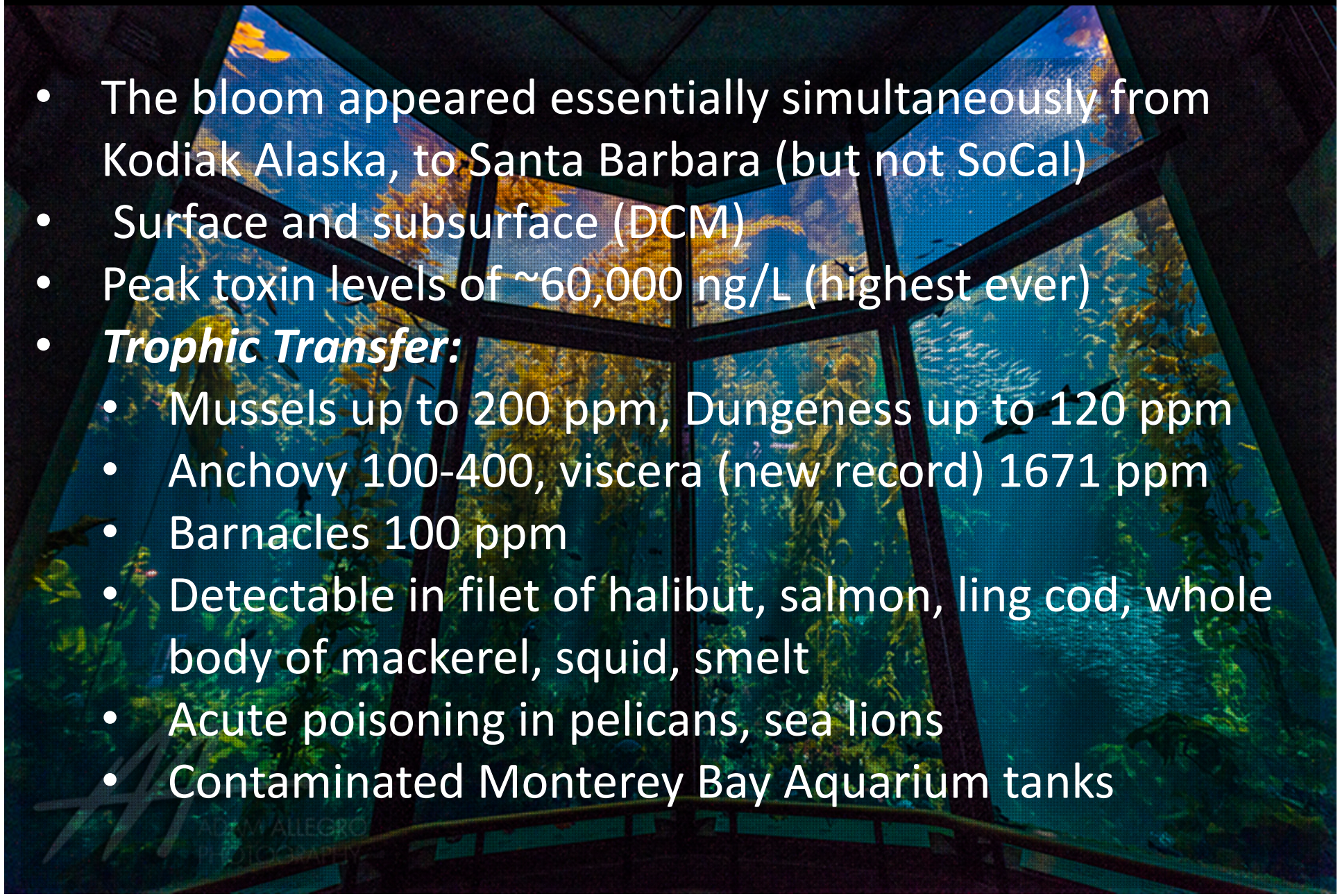
Henry Miller, Statesman Journal 9:12 a.m. PDT May 25, 2015

State quarantine of sport-harvested mussels begins Friday

Rachel Zentz, The Salinas Californian 7:24 a.m. PDT April 29, 2015

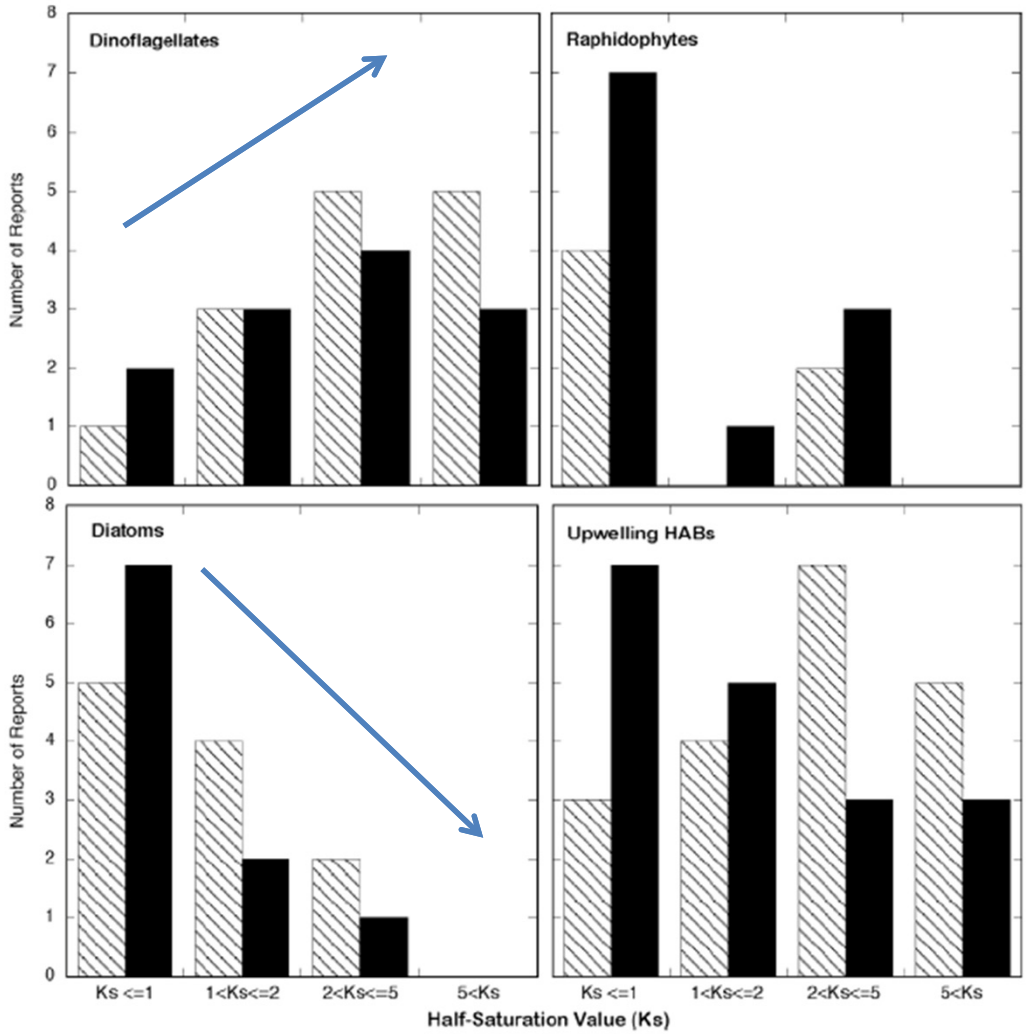
Graphic: Seattle Times

2015: An Unprecedented Year



- The bloom appeared essentially simultaneously from Kodiak Alaska, to Santa Barbara (but not SoCal)
- Surface and subsurface (DCM)
- Peak toxin levels of ~60,000 ng/L (highest ever)
- ***Trophic Transfer:***
  - Mussels up to 200 ppm, Dungeness up to 120 ppm
  - Anchovy 100-400, viscera (new record) 1671 ppm
  - Barnacles 100 ppm
  - Detectable in filet of halibut, salmon, ling cod, whole body of mackerel, squid, smelt
  - Acute poisoning in pelicans, sea lions
  - Contaminated Monterey Bay Aquarium tanks

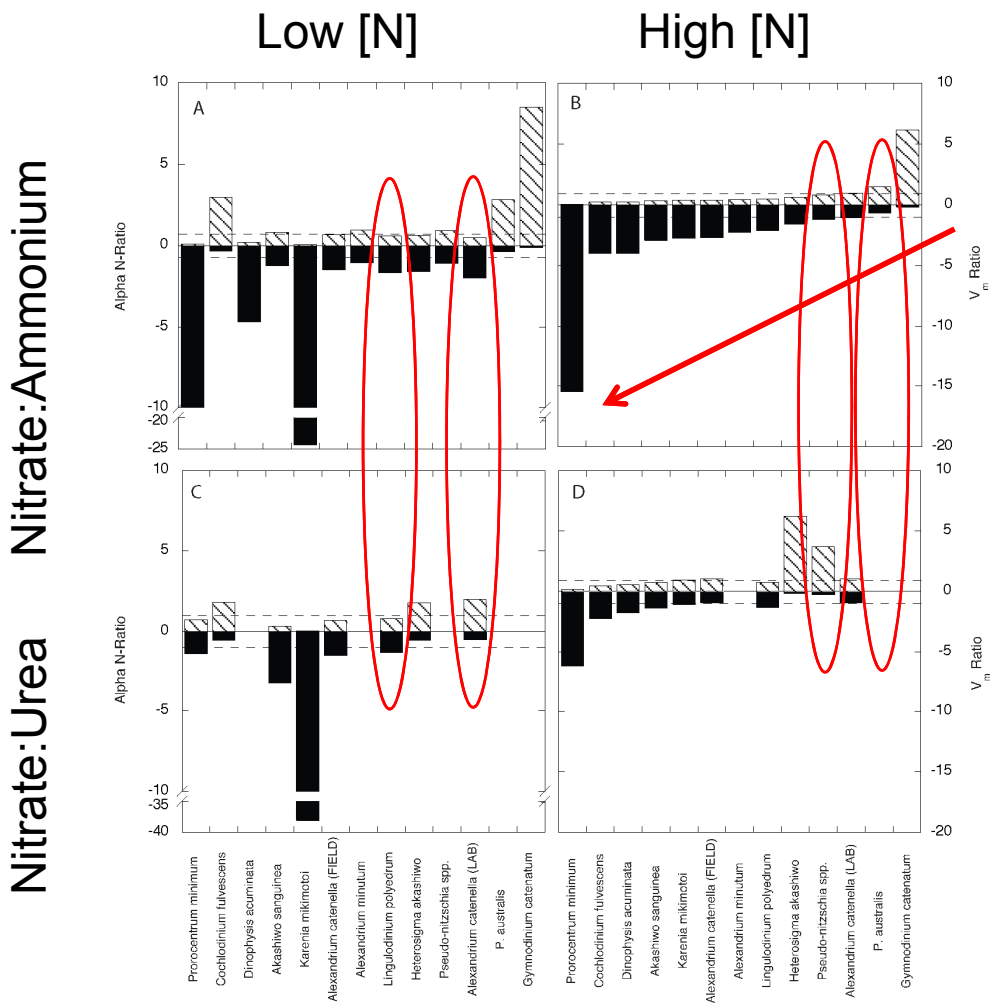
General Patterns of Nutrient Kinetics



Dinoflagellates tend to prefer “high nutrient” environments, Diatoms tend to prefer “low nutrient” environments

Kudela et al., Progress in Oceanography 2010

HABs Generally Prefer Runoff



Eutrophication Potential

HAB organisms found in upwelling systems generally prefer "eutrophic" sources of nutrients.

Pseudo-nitzschia in particular increases toxicity ~10x when given urea

Kudela et al., 2010

A regional comparison of upwelling, coastal land use patterns, and HAB hotspots along the California coast

Raphael Kudela

Clarissa Anderson[1], James Birch[5], Dave Caron[2], Yi Chao[3], Greg Doucette[6], Meredith Howard[4], Burt Jones[2], Drew Lucas[8], Kanna Rajan[5], John Ryan[5], Chris Scholin[5], G. Jason Smith[5], Gaurav Sukhatme[2]

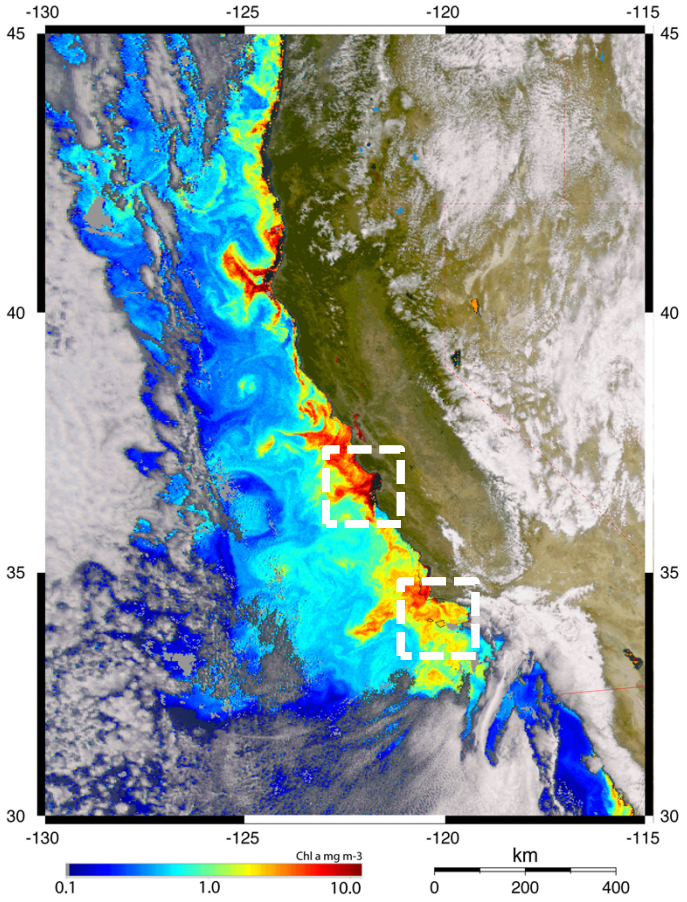
[1]University of California Santa Cruz
[2]University of Southern California
[3]University of California Los Angeles
[4]Southern California Coastal Water Research Program
[5]Monterey Bay Aquarium Research Institute
[6]NOAA Biotoxins Program
[7]Moss Landing Marine Labs
[8]Scripps Institute of Oceanography

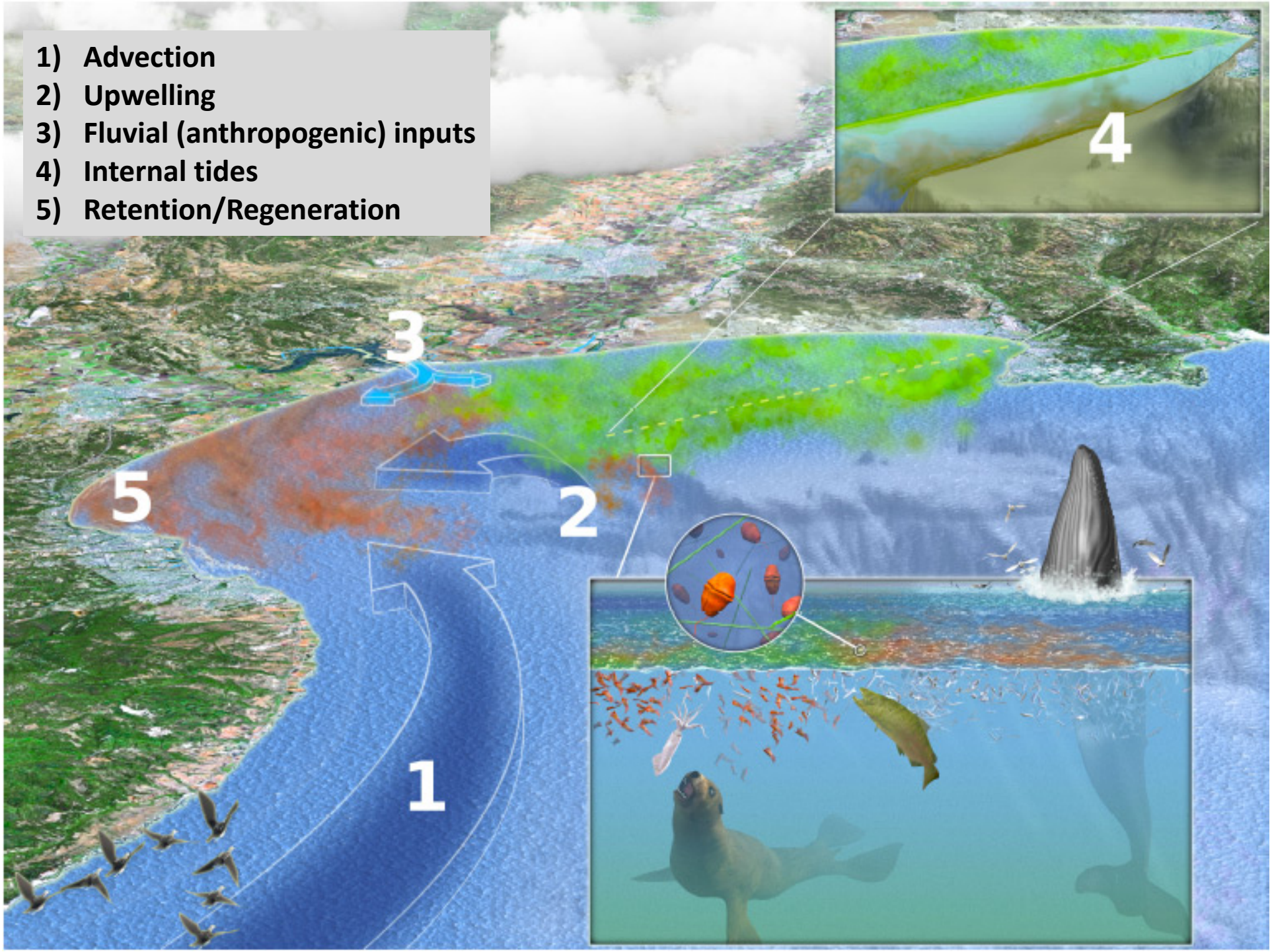
California Harmful Algal Bloom Hotspots

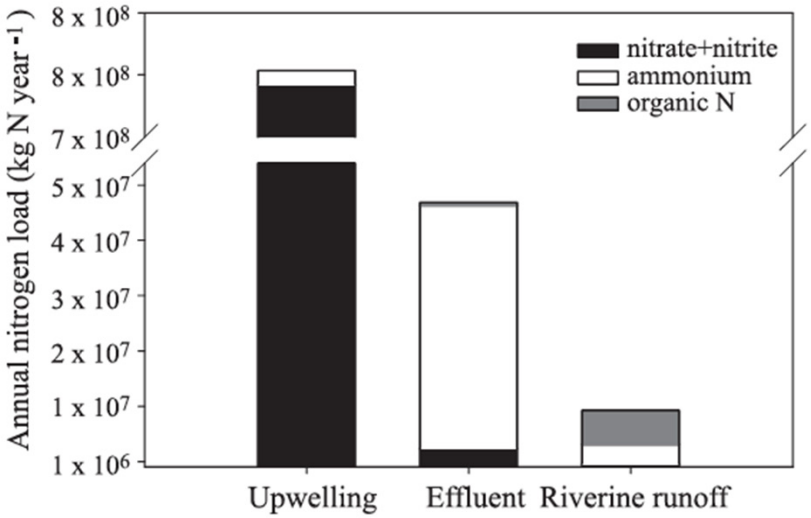
Hypothesis 1: blooms initiate as subsurface features (subsurface maxima) and eventually manifest as surface blooms.

Hypothesis 2: blooms are predominantly the result of advective processes and retention in eddy-like circulation; subsurface maxima are less important.

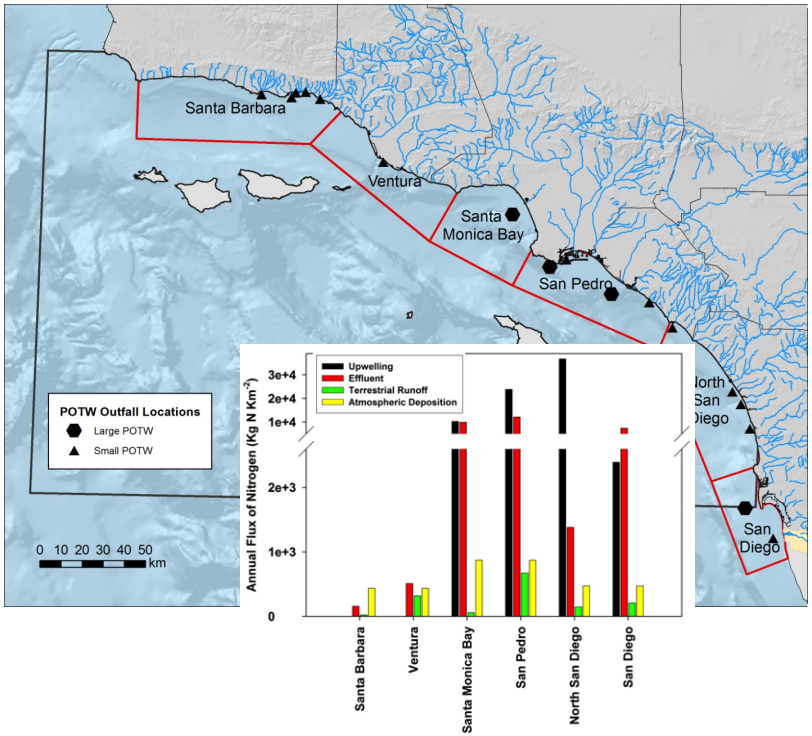
Hypothesis 3: there are a unique set of environmental conditions leading from bloom initiation to toxicity that can be identified through a comparative approach, allowing us to contrast potential factors (such as stratification, nutrient load, nutrient type) between regions.

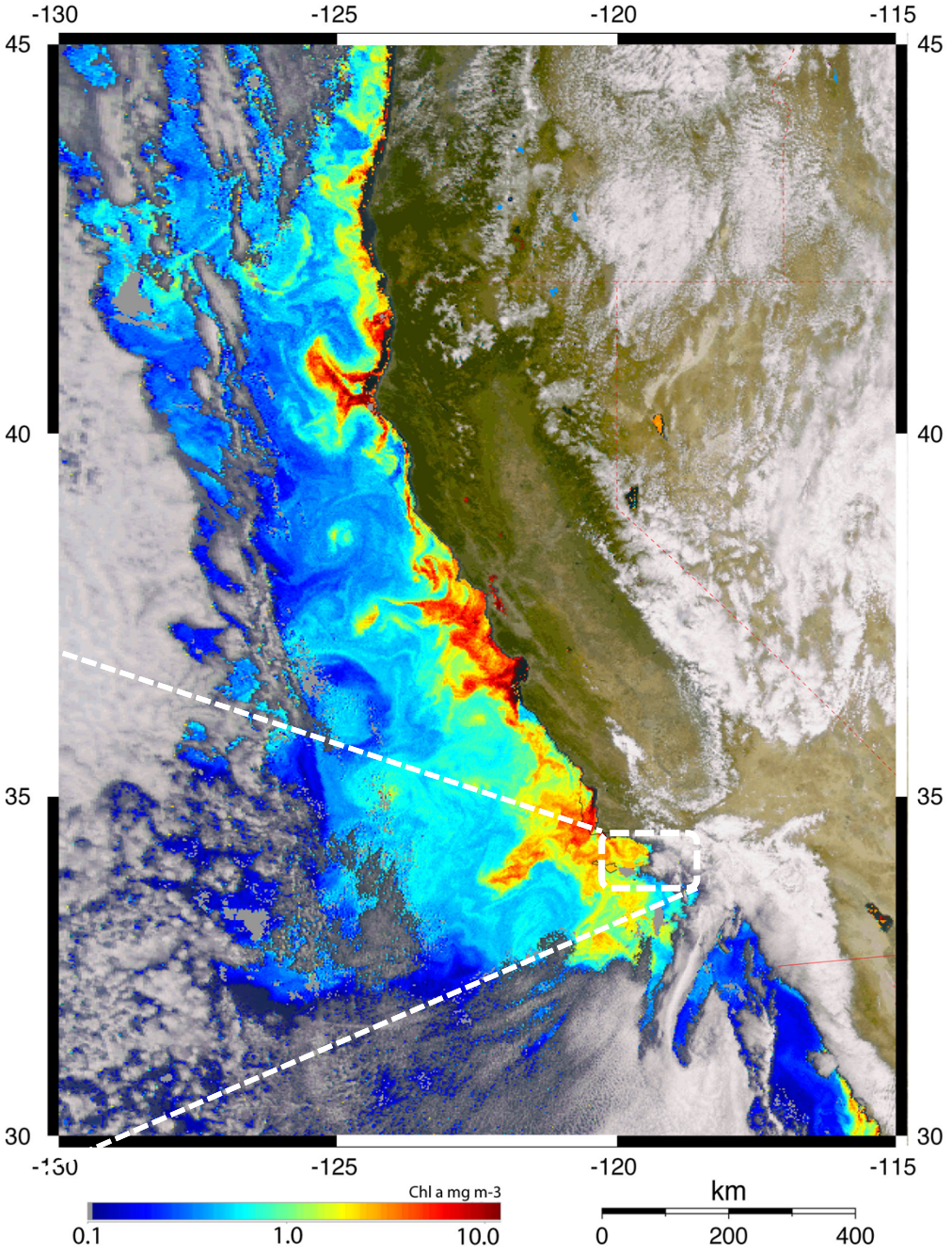



1) Advection
2) Upwelling
3) Fluvial (anthropogenic) inputs
4) Internal tides
5) Retention/Regeneration
1
2
3
4
5



Howard et al., L&O 2014

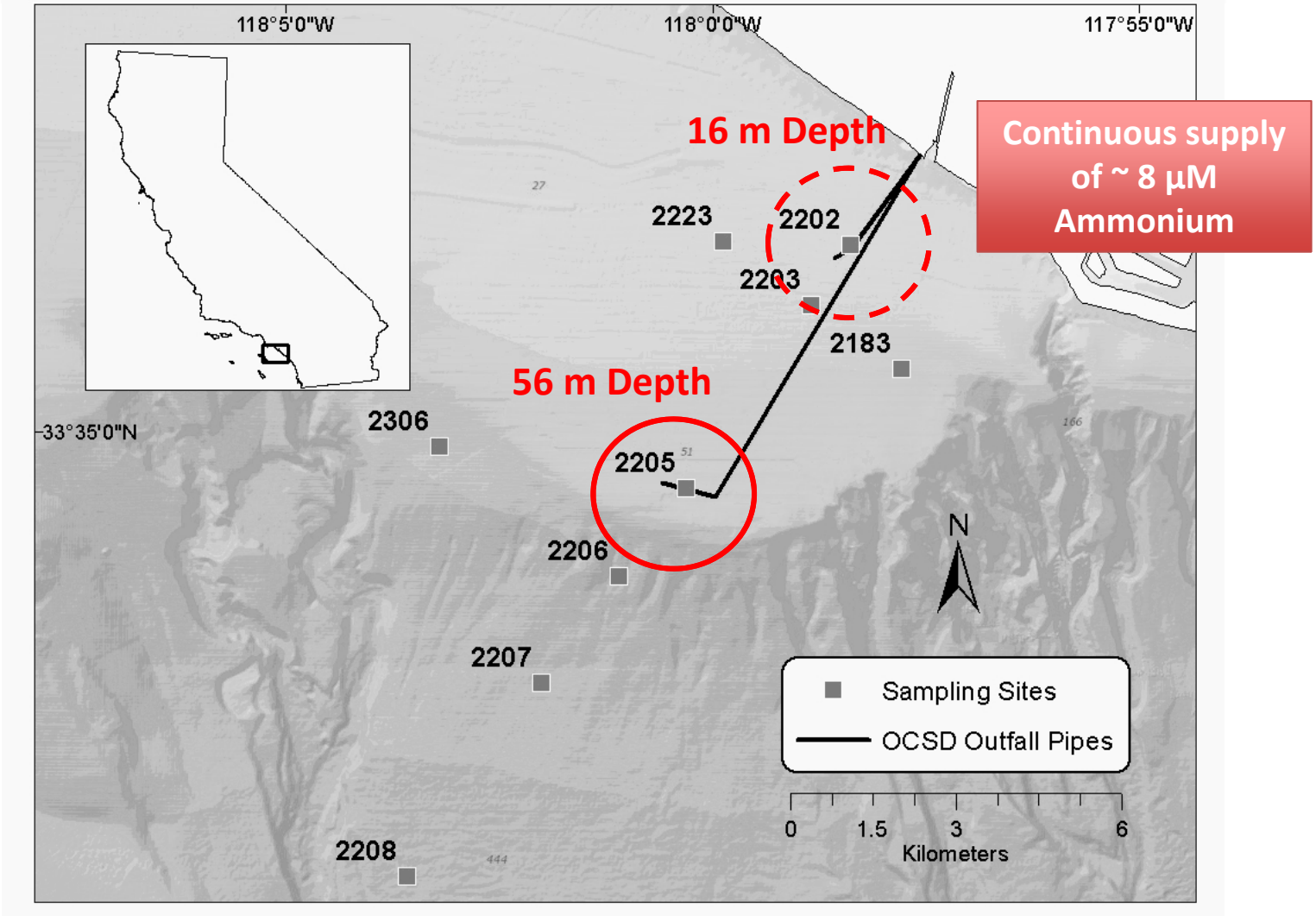


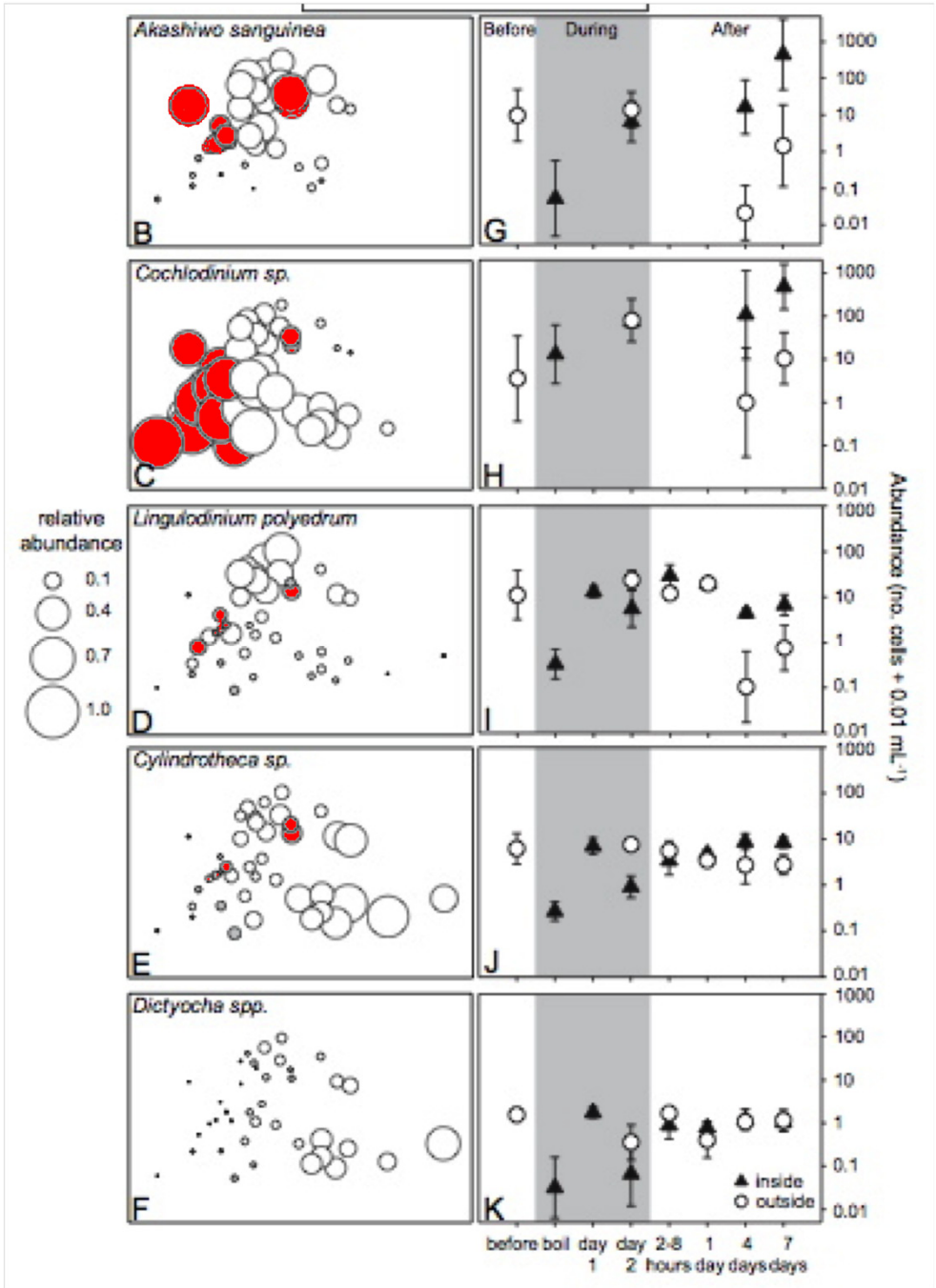


Orange County Sanitation District sewage diversion

~528,000 cubic meters per day effluent

10 Olympic pools per hour, ~21 days duration

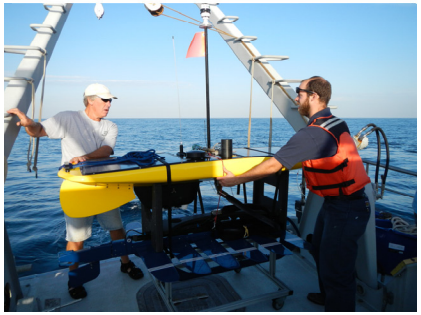


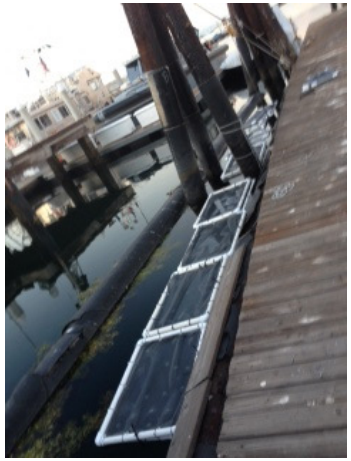


We expected a large biological response, likely driven by HABs

Abundance (left, bubble plots) and response to nutrient enrichment (right) before (white), during (grey) and after (white) diversion of the Hyperion outflow in 2006. The enrichment stimulated several dinoflagellates. Reifel 2009, Reifel et al. 2013.

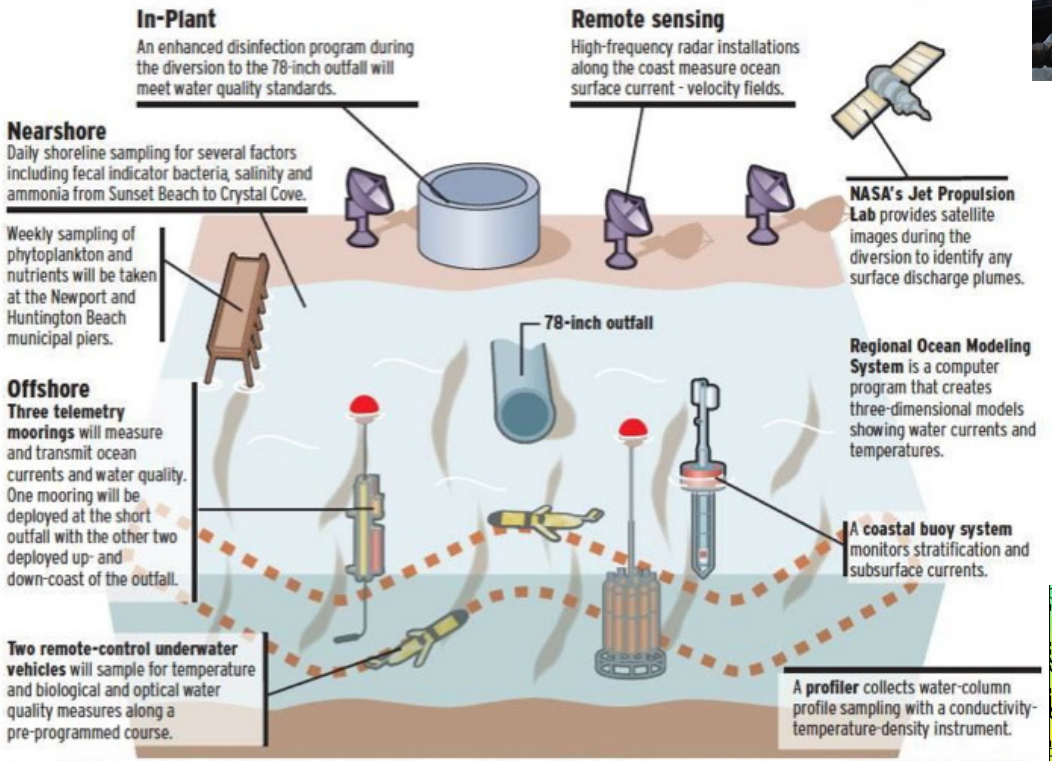
California Harmful Algal Bloom Hotspots

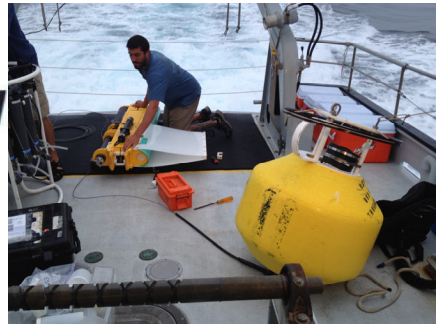


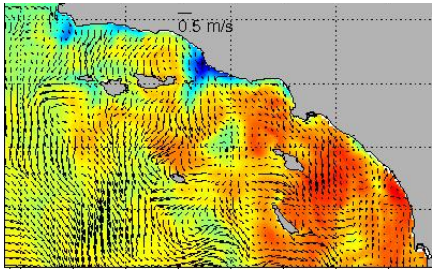


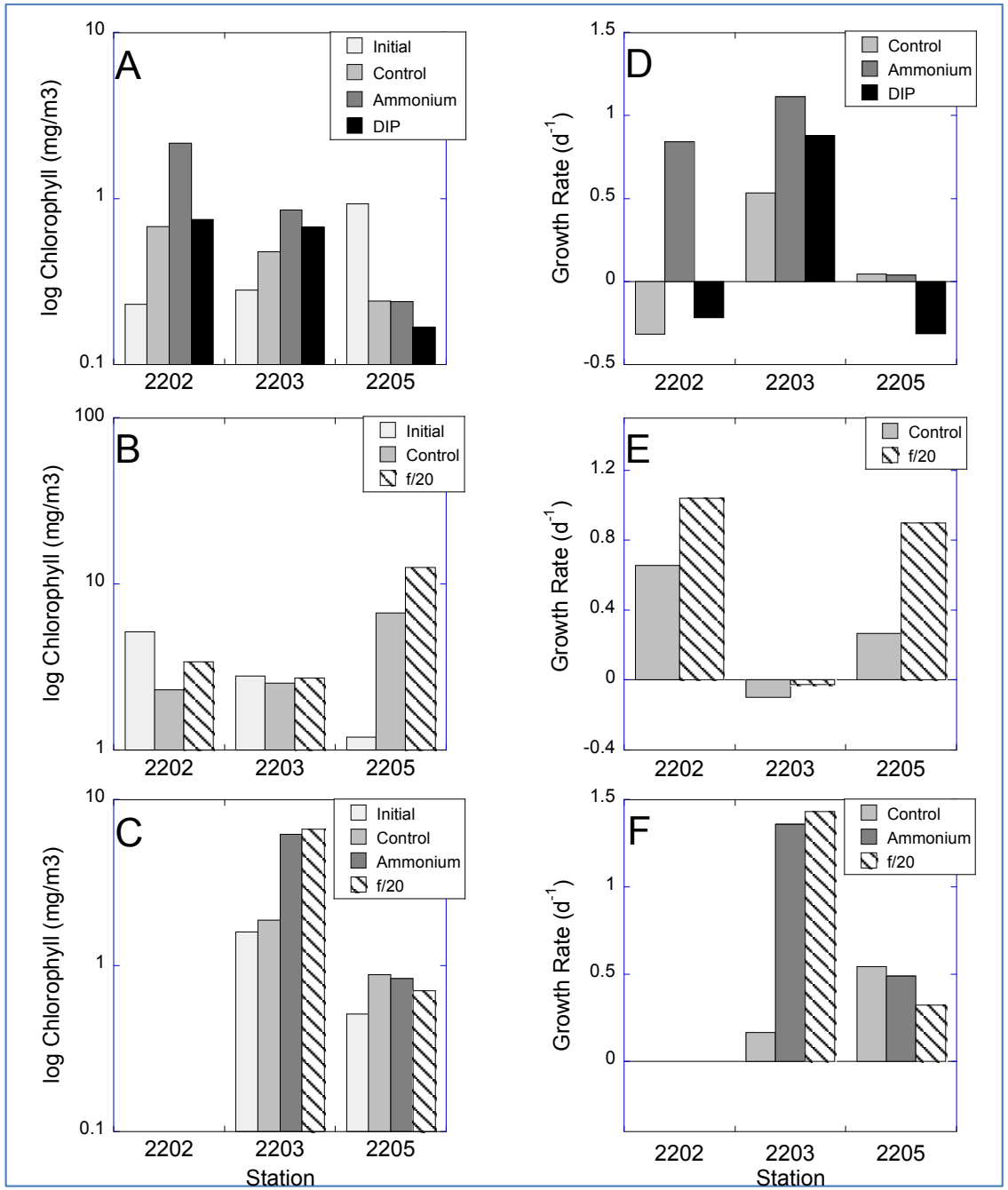
Monitoring water from above and below

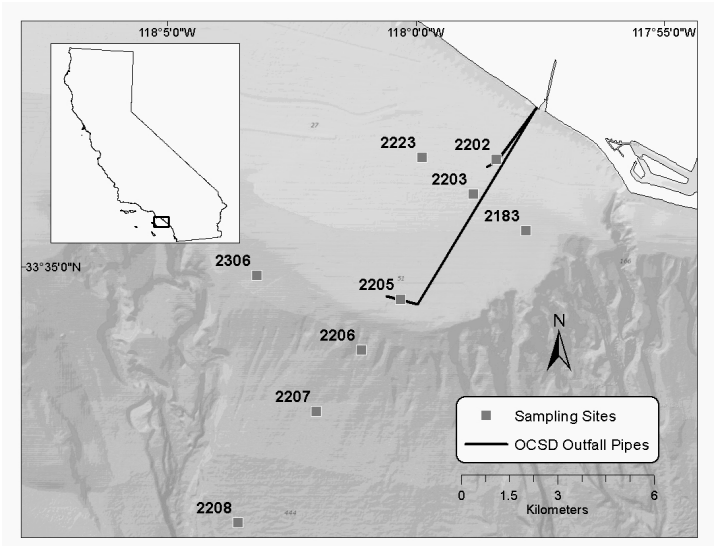
The Orange County Sanitation District is diverting wastewater discharge from its main outfall pipe, 4 1/2 miles offshore, to a shorter, secondary outfall pipe that extends only a mile offshore. That is giving scientists a chance to measure the effects of the treated effluent on algae and other ocean organisms. Boats towing sensors will be part of the extensive ocean monitoring to track the movement of the wastewater plume.







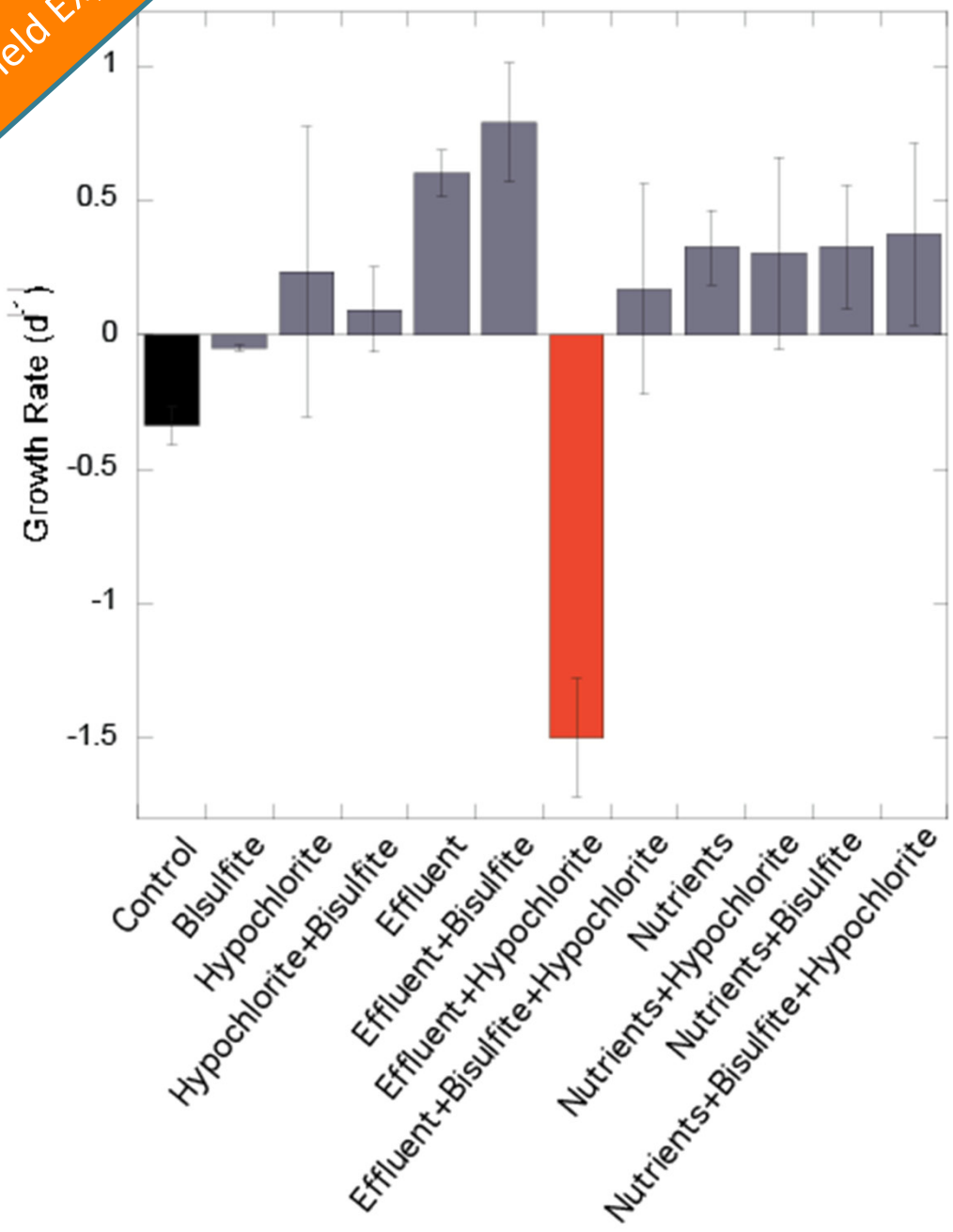




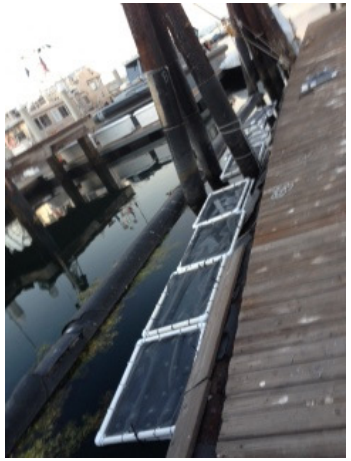
Phytoplankton response to nutrients in bottles shows strong, positive growth when given a nitrogen source…

…Kinetics data shows no sign of ammonium inhibition.

Field Expt.



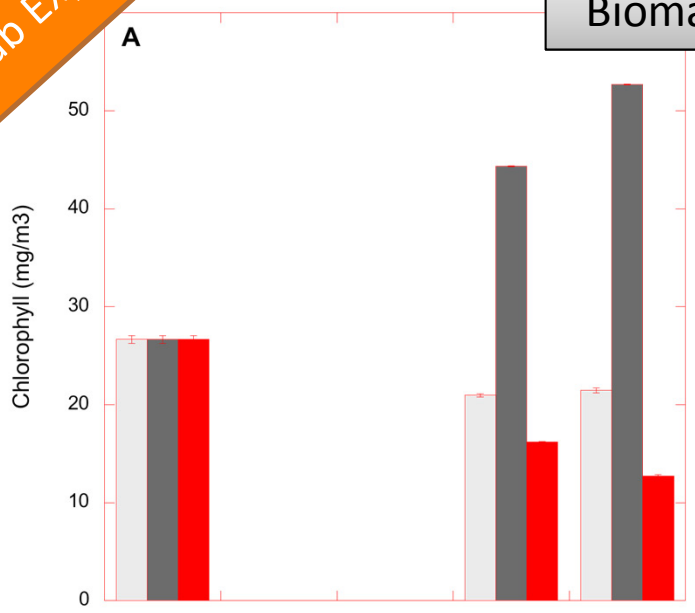
Could it be the Effluent?



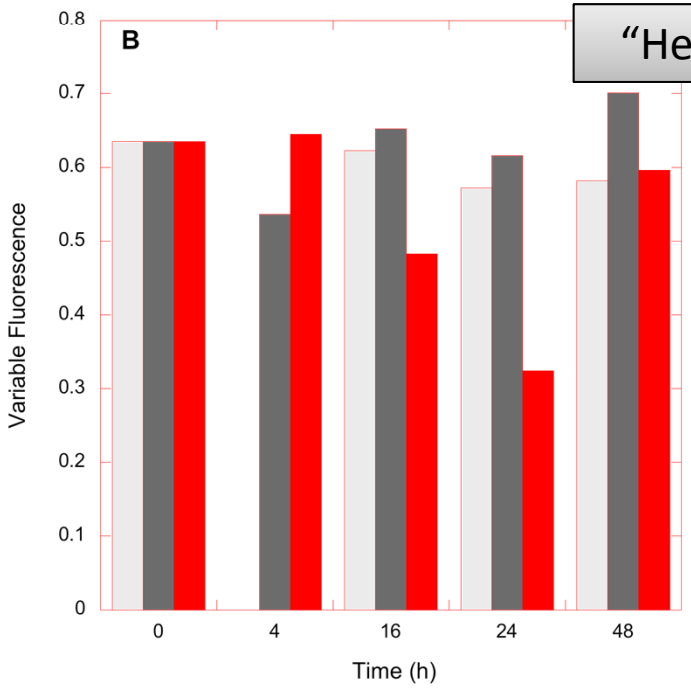
We simulated the conditions used in the diversion: chlorination & dechlorination in the presence of organics

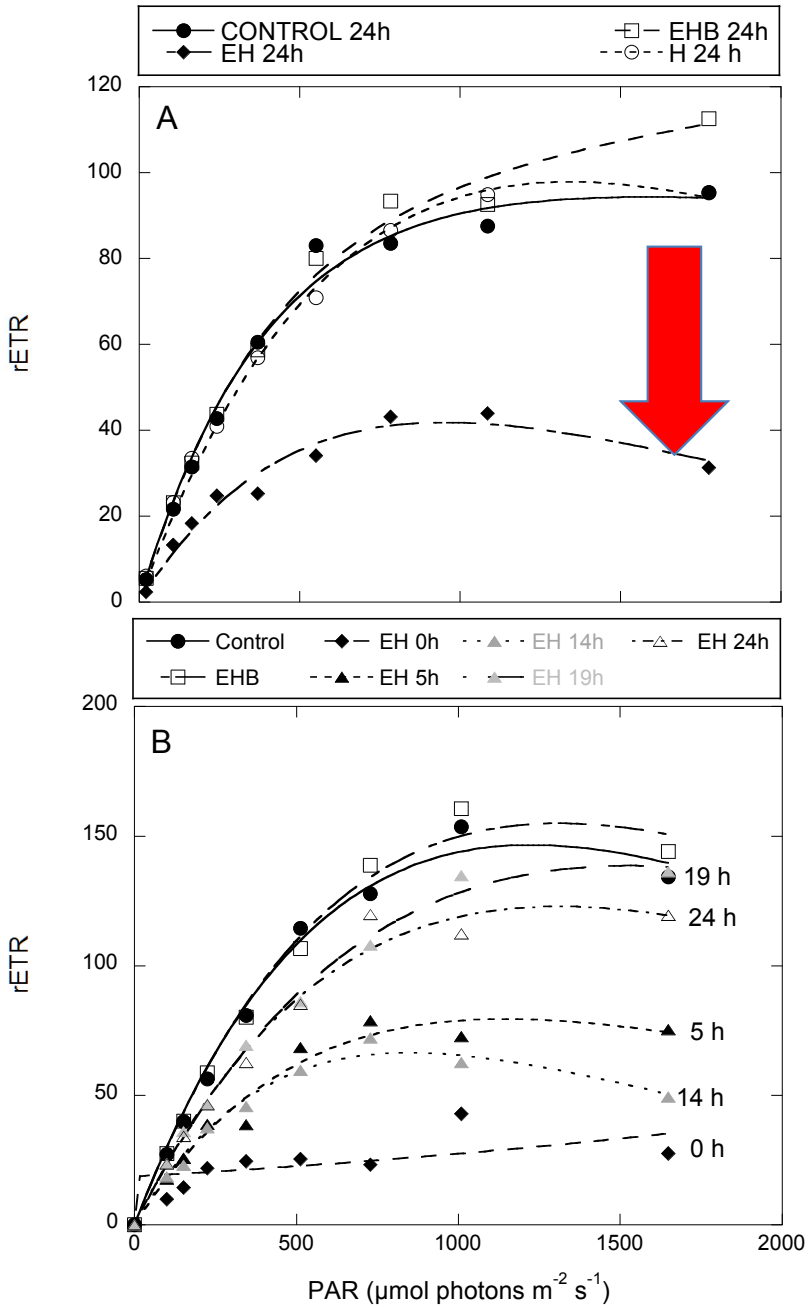
Lab Expt.

Biomass



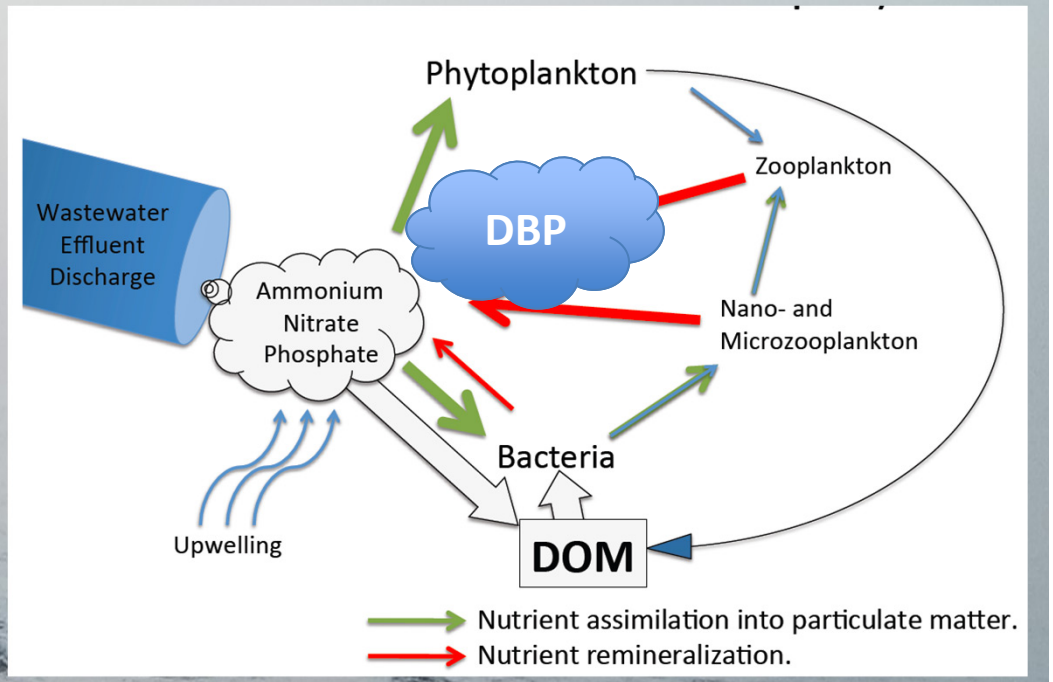
"Health"





Chlorine and equilibrium formation of hypobromous acid and hypobromite reacts with ammonium to form a "bewildering array of products"

-- Jolley 1973



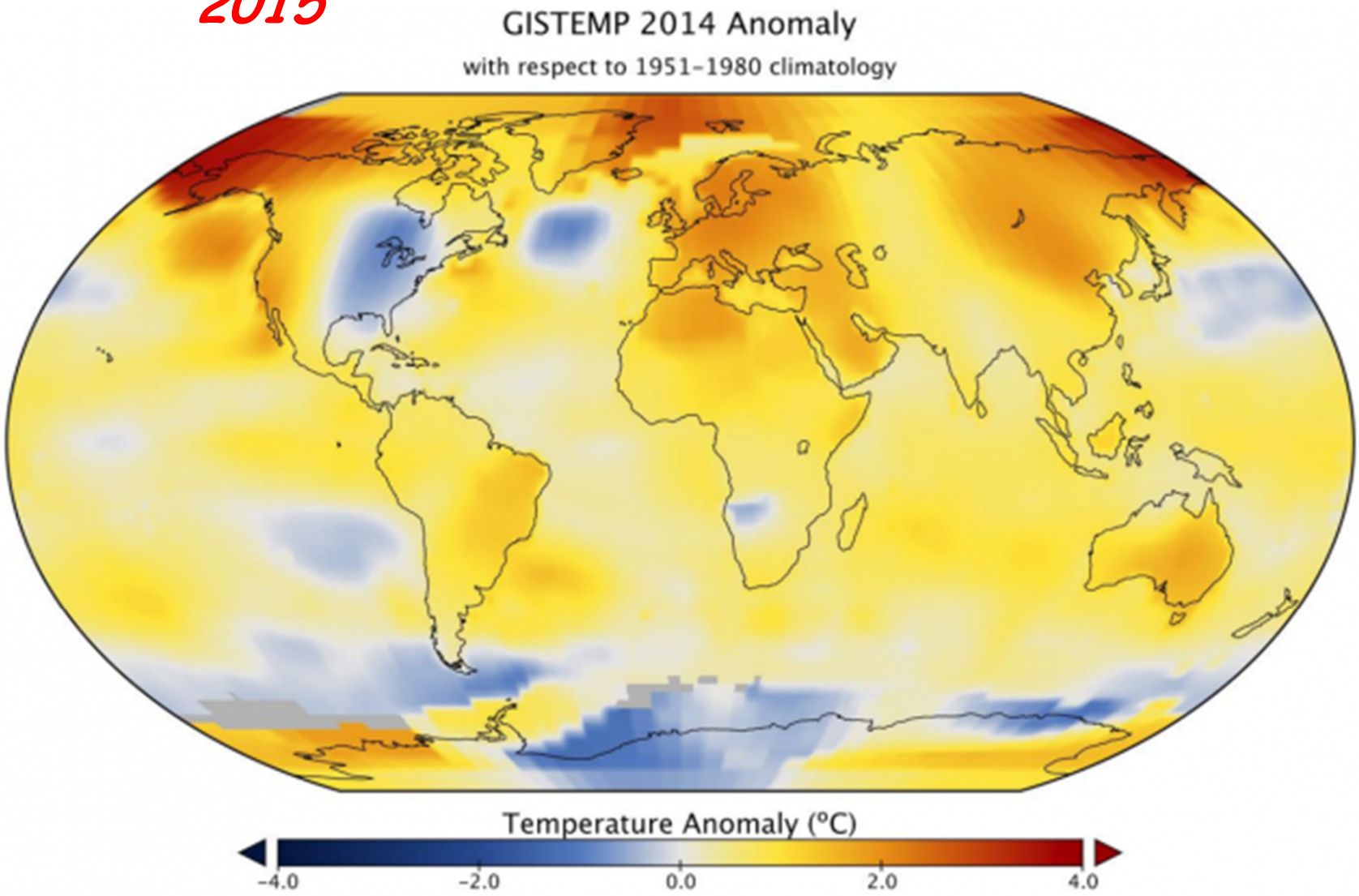
Phytoplankton are particularly sensitive to haloacetic acids and that brominated compounds produced by chlorination of seawater would presumably be similar to chlorinated compounds.

-- Agus et al. 2009

These Disinfection Byproducts (DBP) are found in rivers, wastewater, drinking water, treated ballast water, desalination systems, swimming pools, with more than 1,000 compounds identified so far…. Many are mutagenic and carcinogenic. ~100 have been well characterized, and a small handful have been regulated

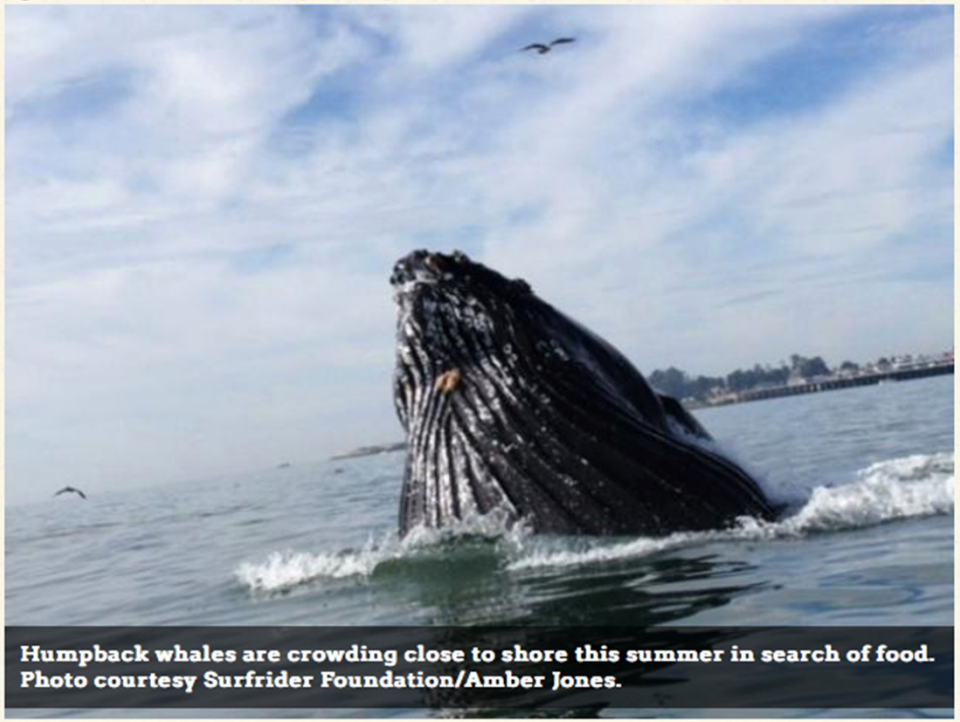
2014: The Warmest Year In the Modern Record

2015



The Summer of Crazy

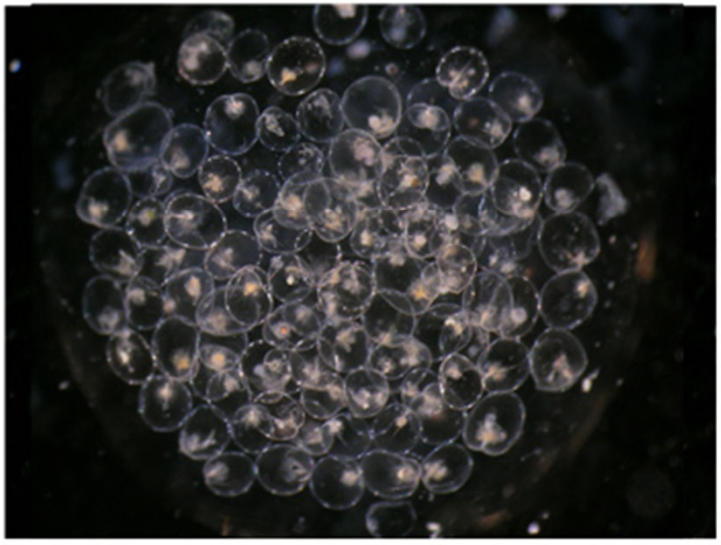
Tags: *whales* *whale watching* *humpback* *anchovies* *domoic acid* *El Nino*



Humpback whales are crowding close to shore this summer in search of food. Photo courtesy Surfrider Foundation/Amber Jones.

http://www.hilltromper.com/article/monterey-bay-weird-summer-2014-whales-anchovies-algae

haddock@mbari.org • http://lifesci.ucsb.edu/~biolum • http://jellywatch.org

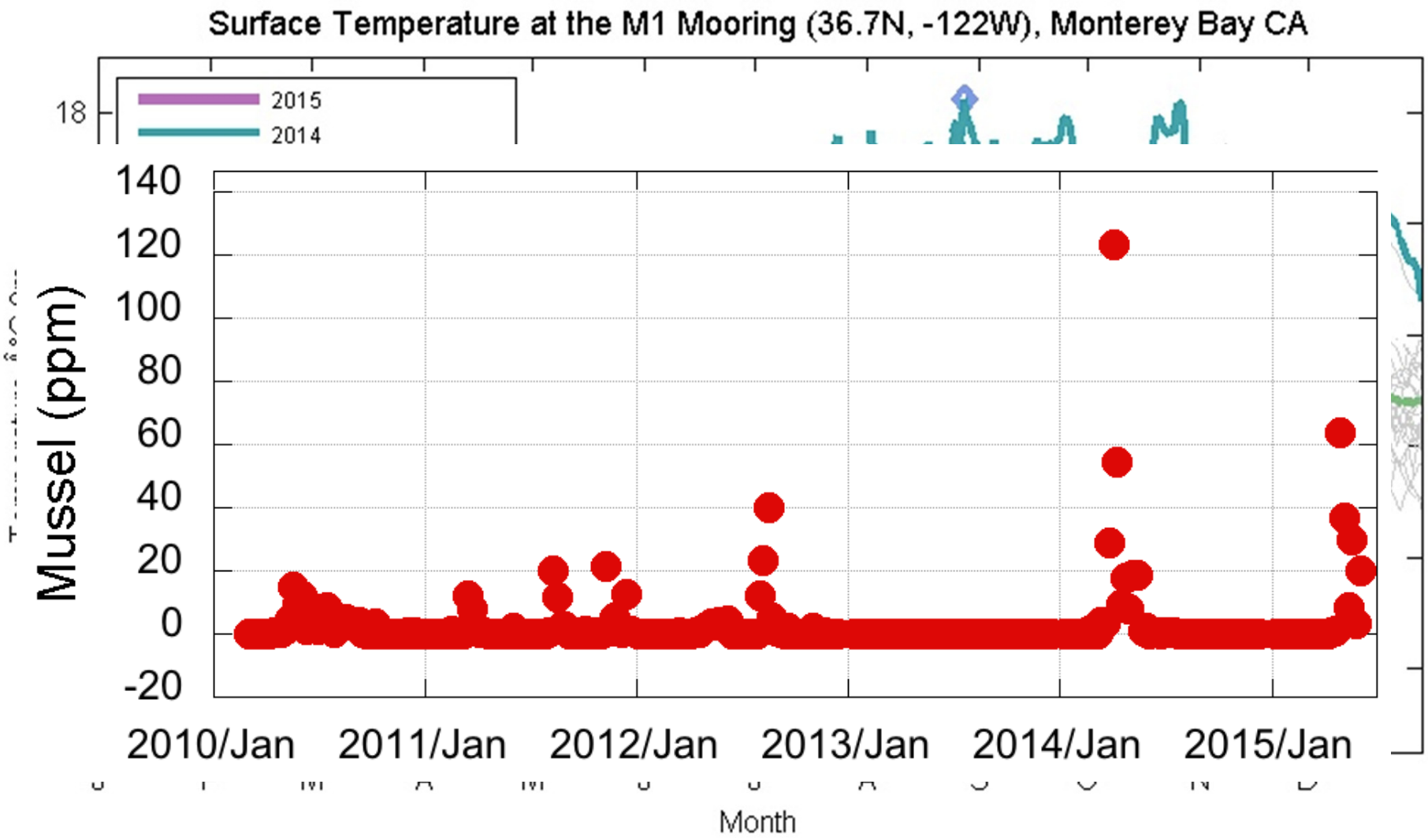


Beachings of exotic blue velella tied to wind patterns

Velella, probably carried by wind, a reminder of ocean's diversity

Hamed Aleaziz Updated 7:14 pm, Thursday, July 31, 2014

Green stuff on Seaside beach probably common marine algae



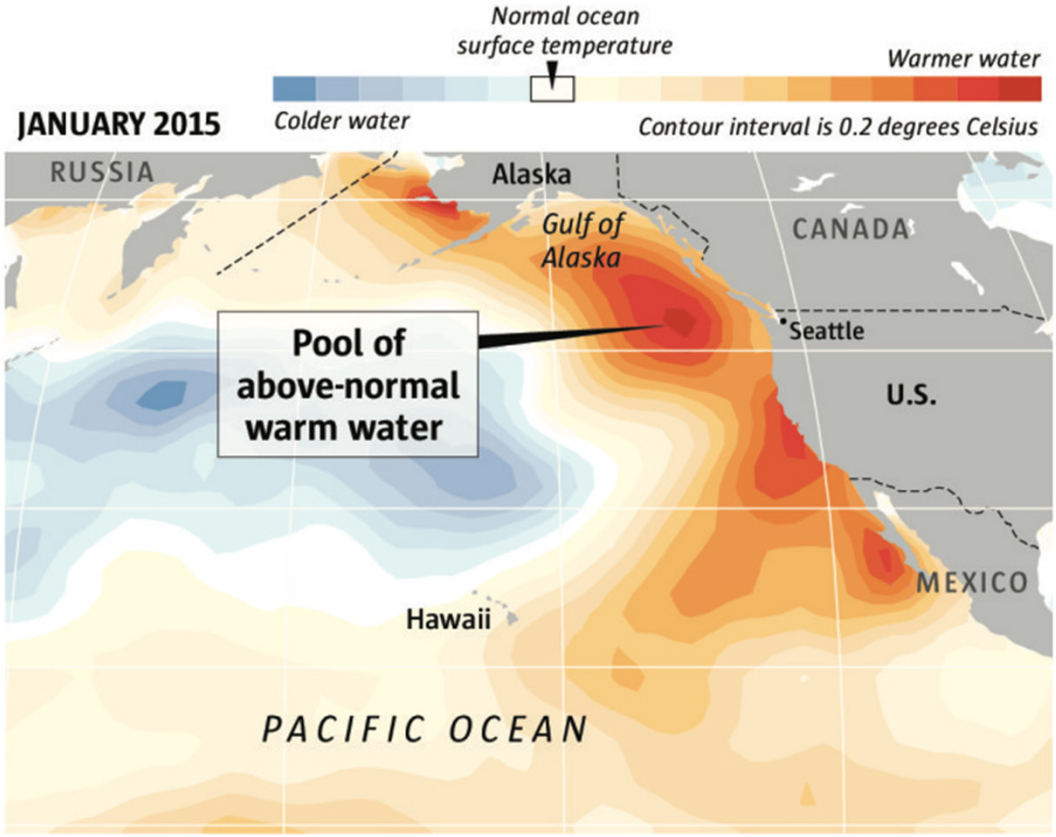
Climatology Minimum on 25-May-1991, 8.025Â°C; Maximum on 27-Aug-2014, 18.24Â°C
2015 YTD Minimum on Jan-03, 13.47Â°C; Maximum on Jan-16, 14.93Â°C

Monterey Bay Aquarium Research Institute: http://www.mbari.org
Contact: reiko[at]mbari.org

Updated:16-Jan-2015

The blob off our coast

Scientists say a vast pool of warm water off our coast is affecting marine life and local weather, and is part of a bigger pattern that includes California's drought and East Coast blizzards.



Source: Department of Atmospheric Sciences, University of Washington

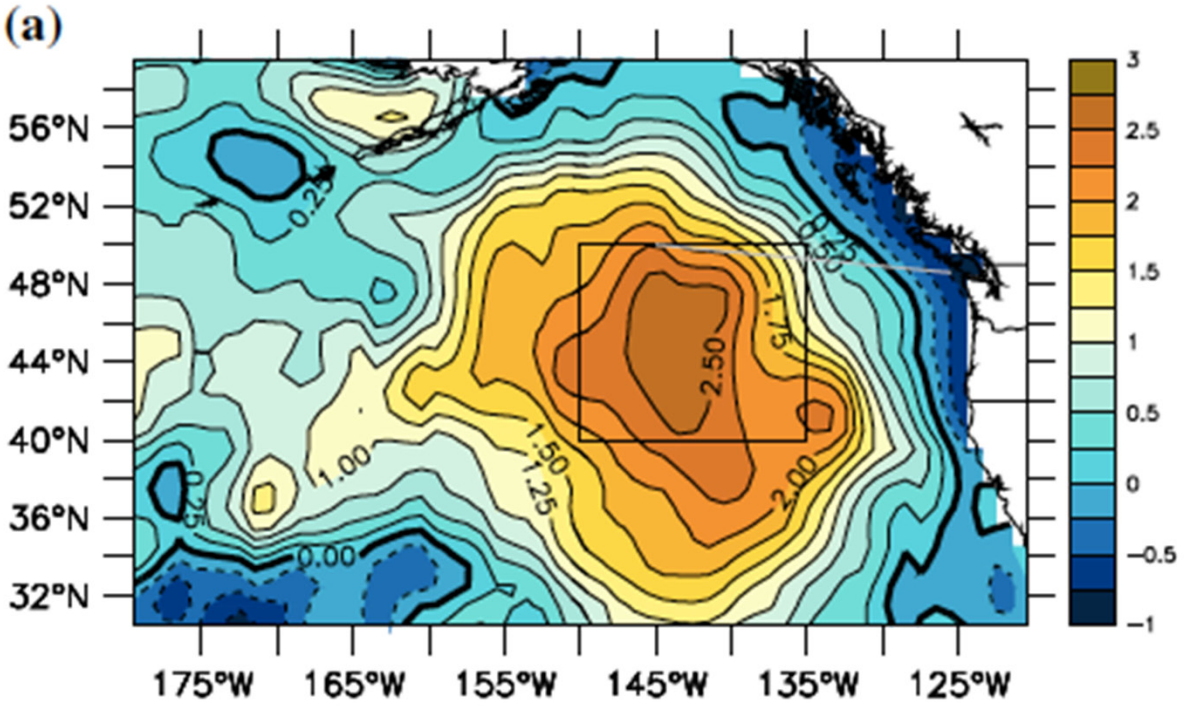
MARK NOWLIN / THE SEATTLE TIMES

KQED Science

NEWS | PROGRAMS & BLOGS | EDUCATION RESOURCES

DROUGHT WATCH 2015

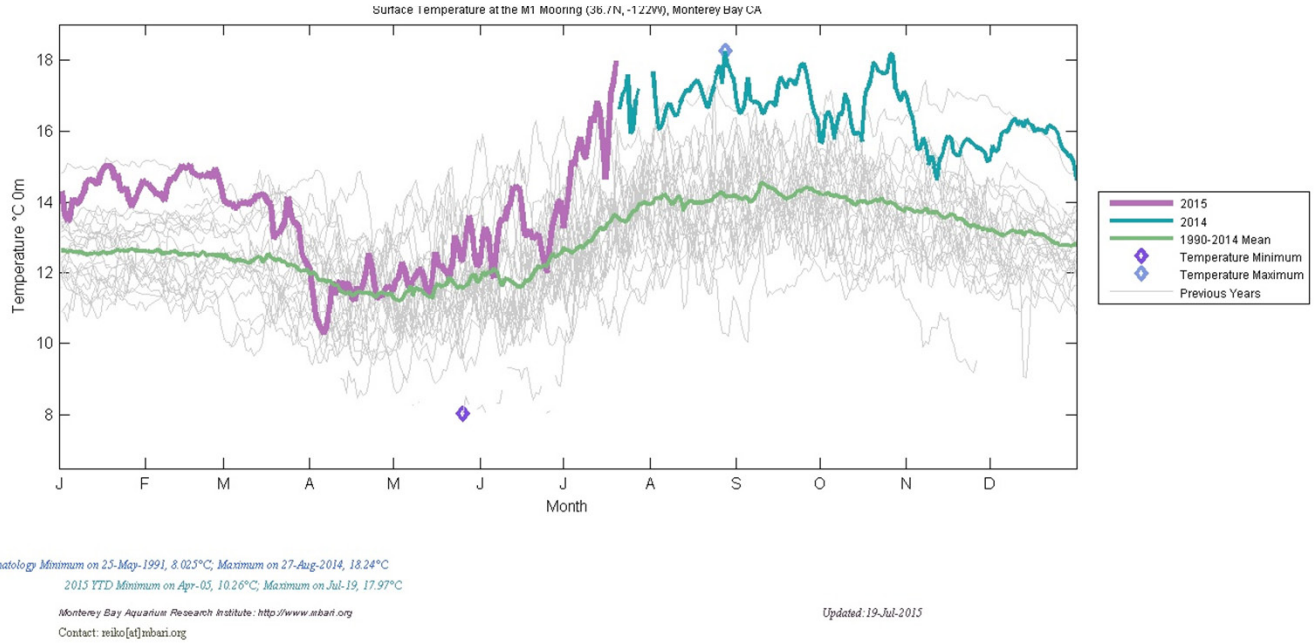
El Niño Update: California's 'Great Wet Hope' Continues to Build



SST Anomaly, February 2014

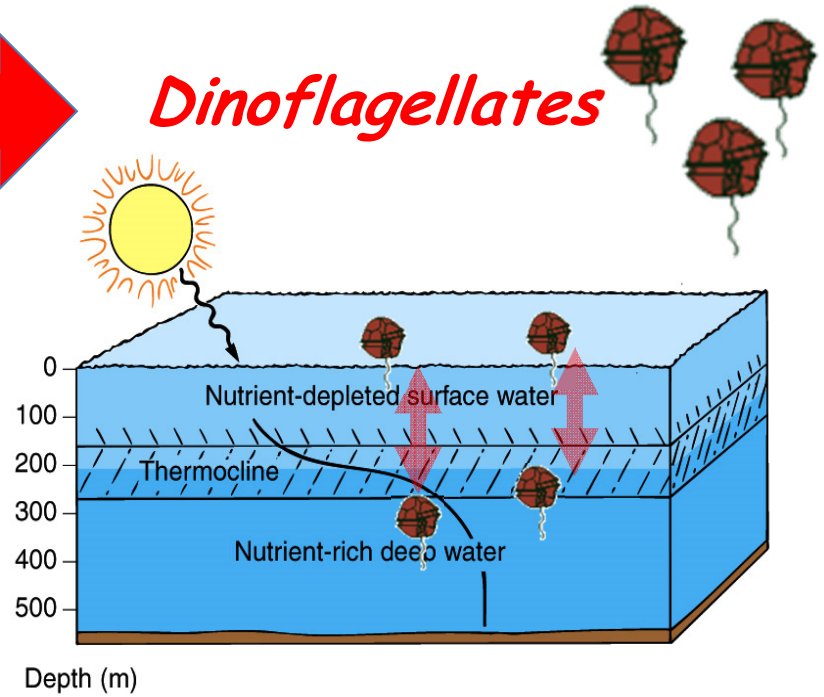
Bond et al. GRL 2015

MBARI M1 Temperature Anomalies, 2015

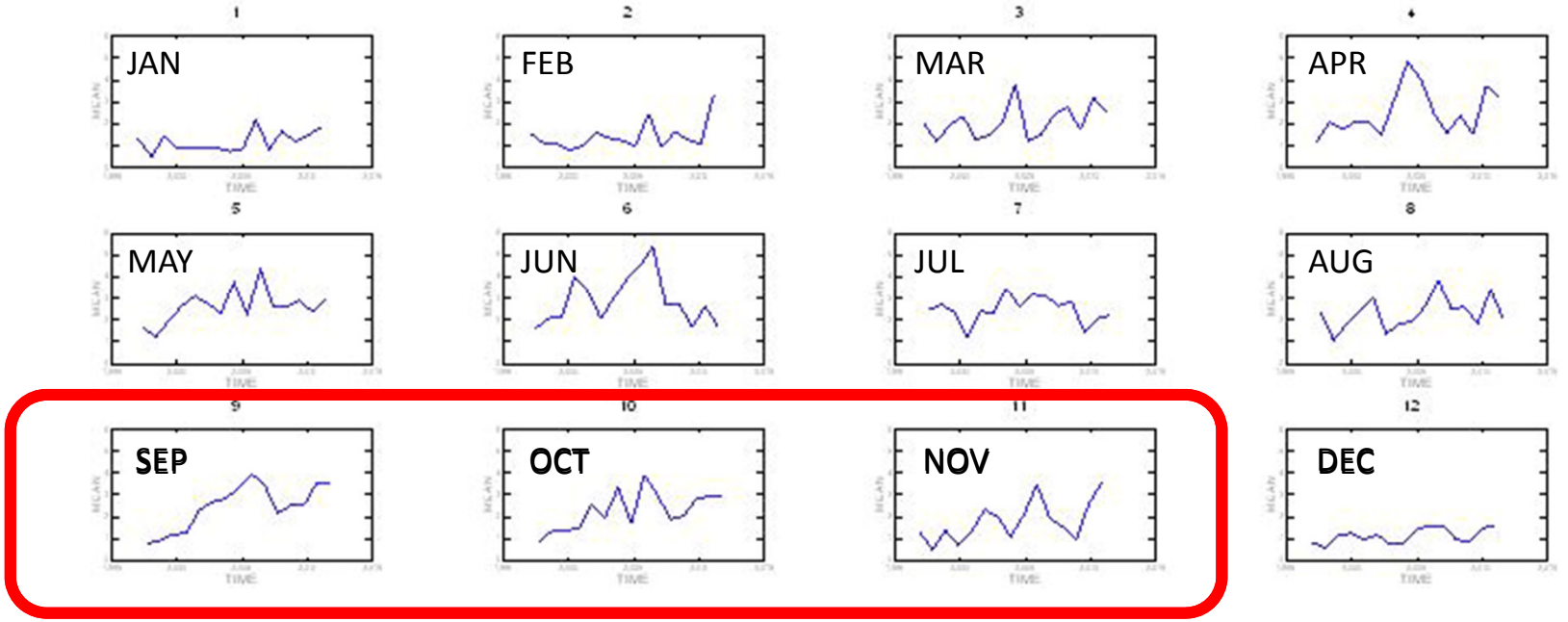


Decadal Trends in the California Current:

- Mixed Layer Depth is shoaling
- Surface temperatures are increasing
- Stratification intensity is increasing
- Nutrient concentrations, ratios shifting



Mean Monthly Trends in Chlorophyll



Decadal Trends in the California Current:

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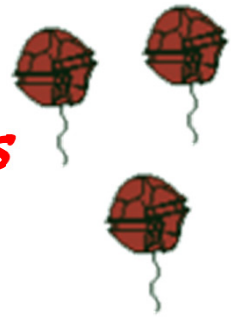
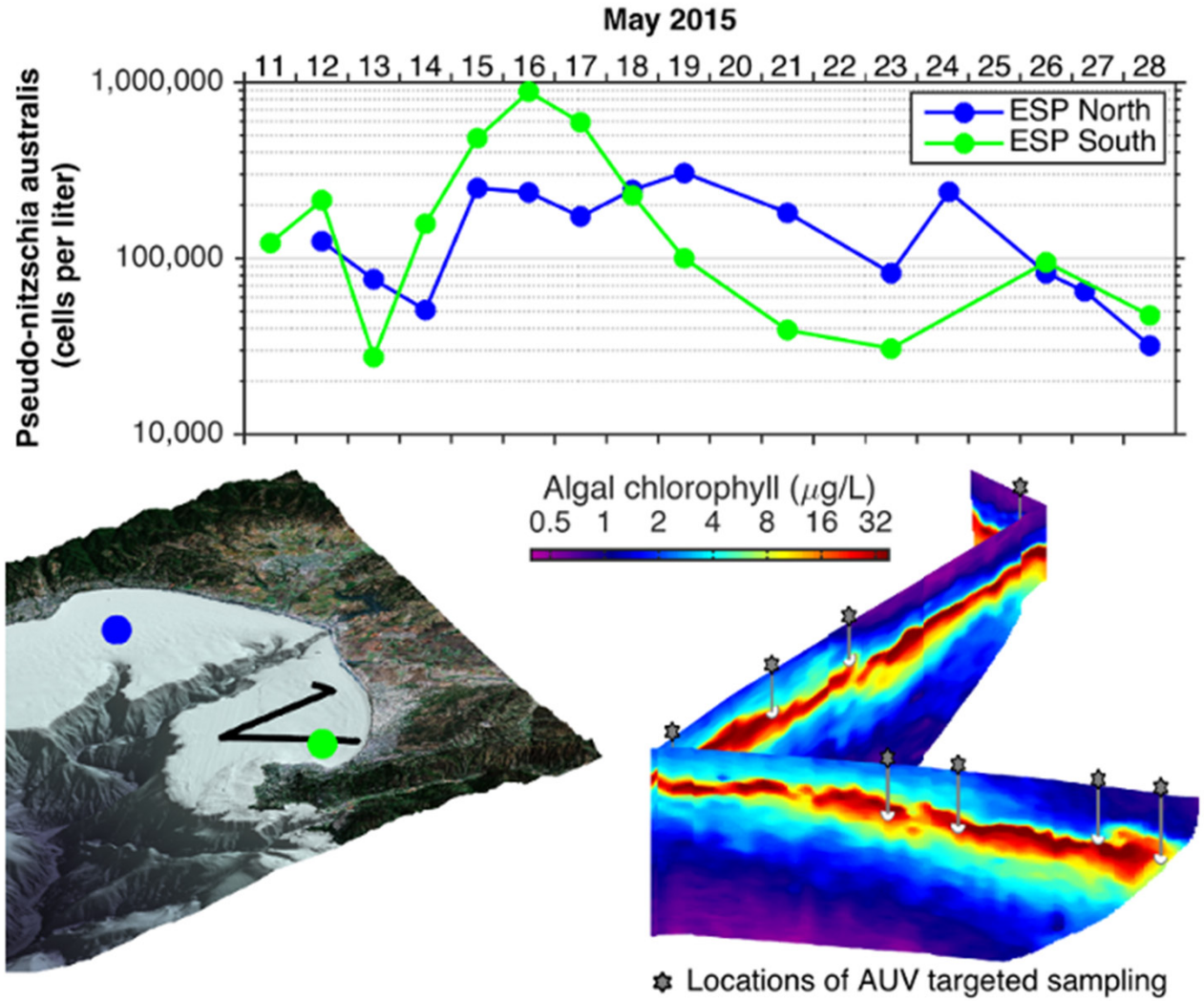
- Nutrient concentrations, ratios shifting

Dinoflagellates



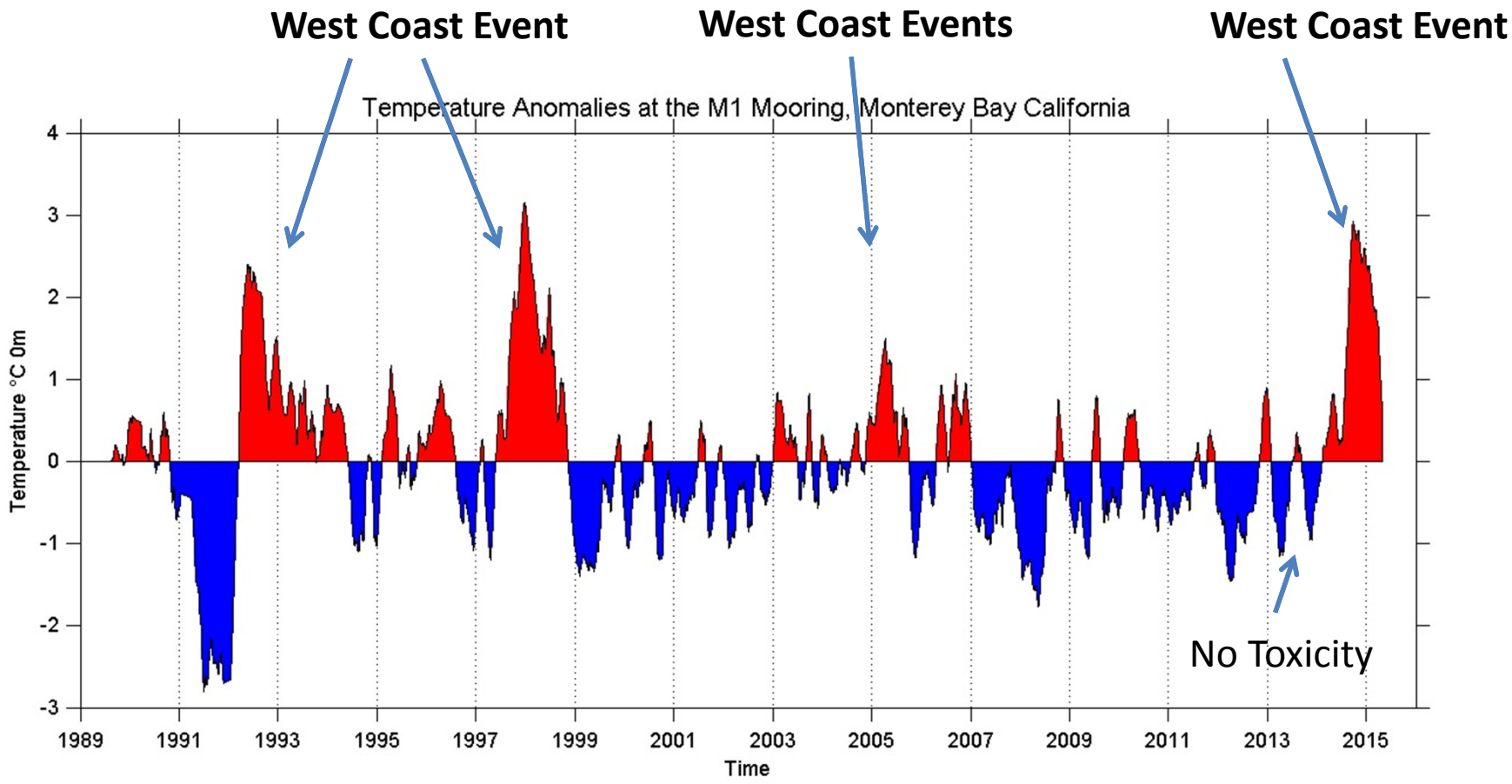
2015 data from Monterey showing the development of a subsurface layer of *Pseudo-nitzschia* (sitting on the nutricline). Previous studies show coupling with high-Fe waters from BBL feeding these layers.



Pseudo-nitzschia—the diatom that thinks it's a dinoflagellate

- Generally prefers runoff (urea, ammonium) but has an elevated V_{max} and growth rate on all N sources
- Often found in subsurface layers (in contact with the nutricline, also in contact with the BBL, possible Fe-acquisition)
- Prefers warm water, weak pulsed upwelling
- Toxicity driven by nutrient stress, slowing growth, urea
- We would generally expect it to bloom during anomalously warm, pulsed nutrient conditions (i.e. El Niño), which are the same conditions that collapse the food web towards the coast…

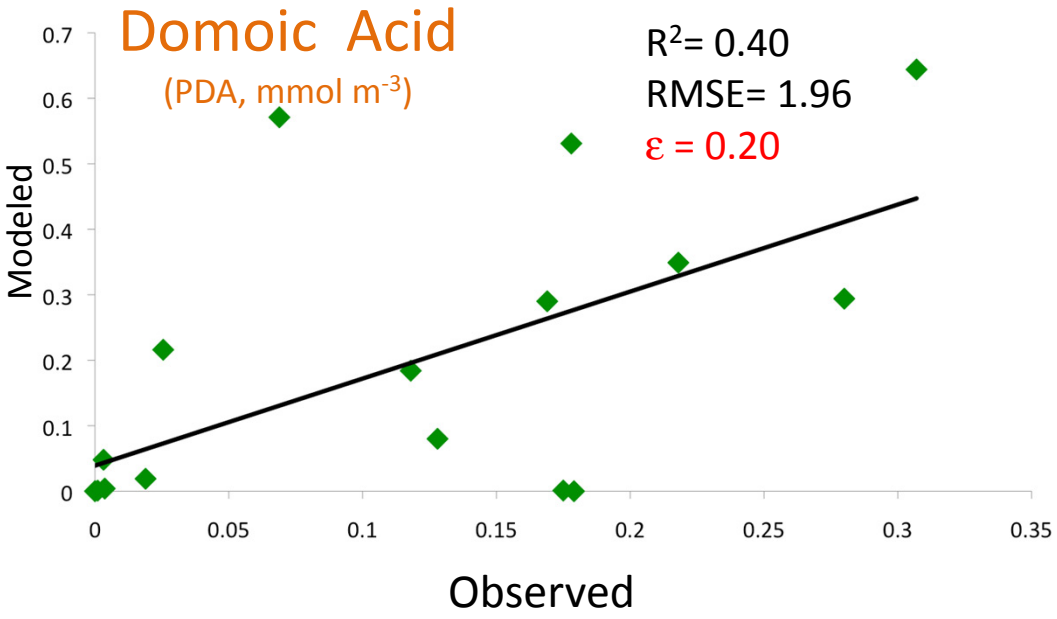
2014—The Summer of Crazy
2015—Massive Bloom (largest ever?)
2016—Even worse?

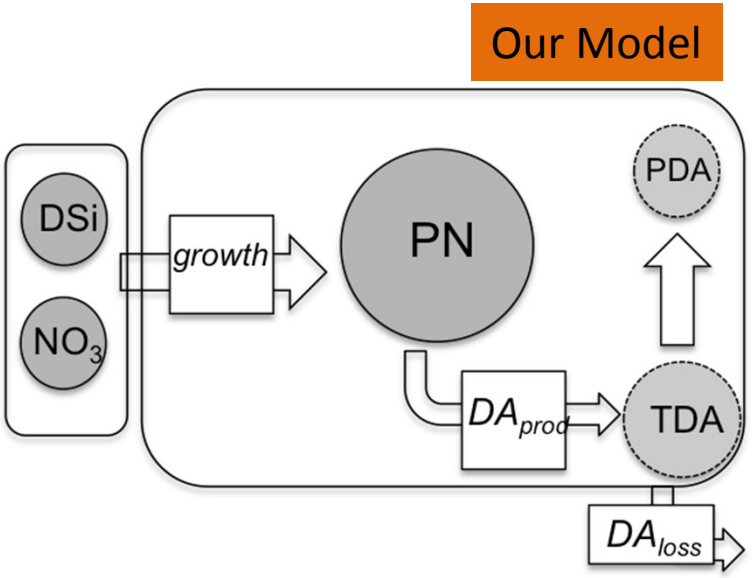


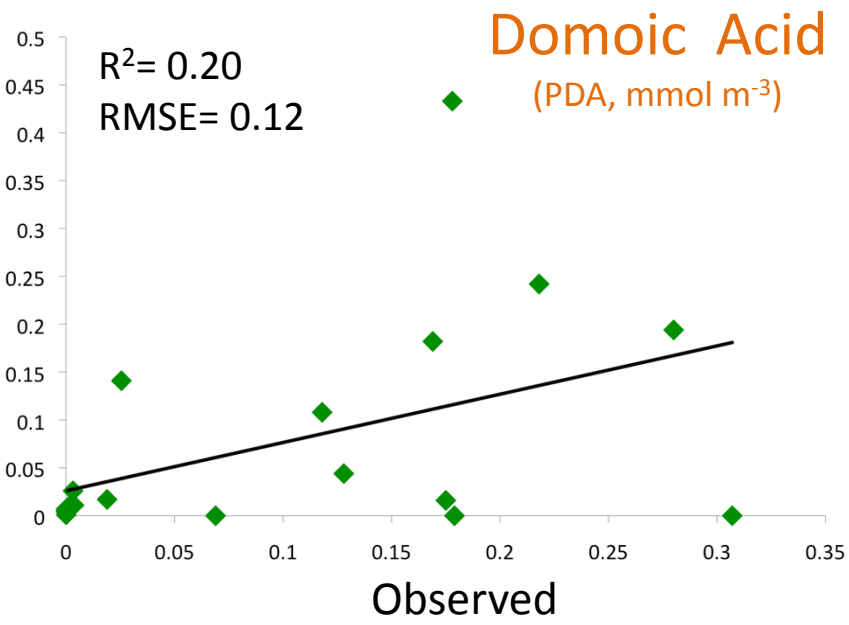
Note: 60 point moving average applied to daily averaged values.

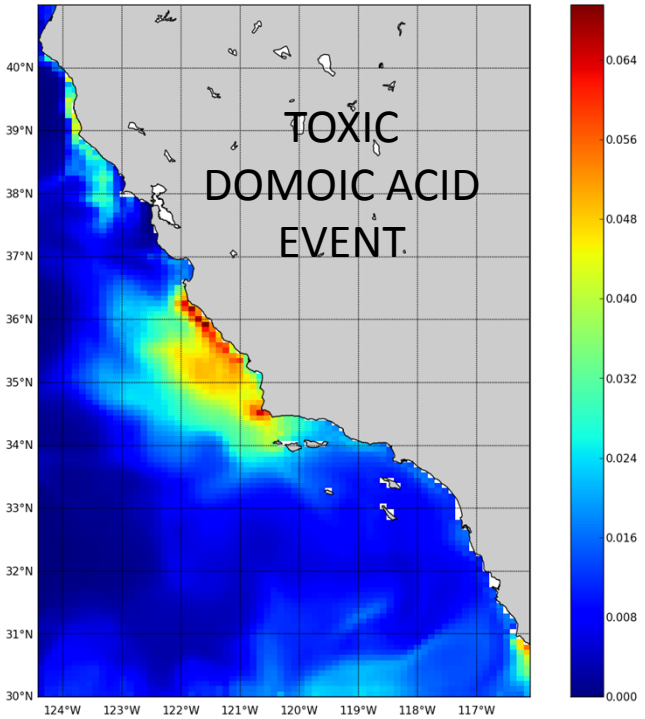
Monterey Bay Aquarium Research Institute

Updated:20-Jul-2015


Domoic Acid
(PDA, mmol m-3)
R2= 0.40
RMSE= 1.96
ε = 0.20
Modeled
Observed
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35


Our Model
DSi
NO3
growth
PN
PDA
DAprod
TDA
DAloss


Domoic Acid
(PDA, mmol m-3)
R2= 0.20
RMSE= 0.12
Observed
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

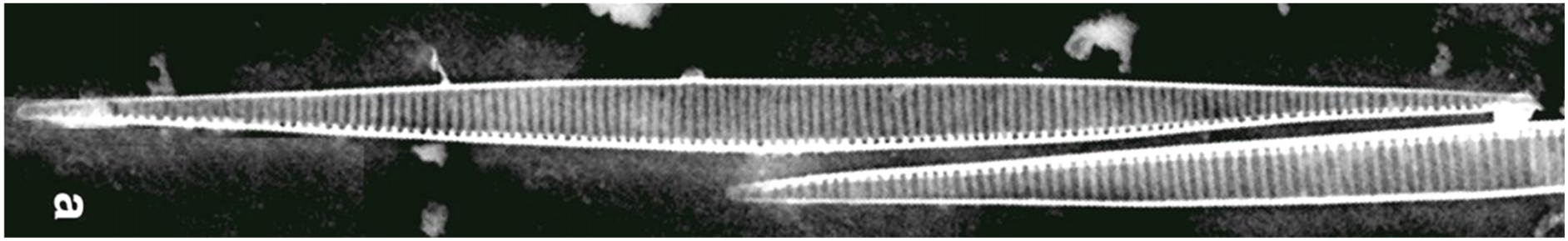

TOXIC
DOMOIC ACID
EVENT
40°N
39°N
38°N
37°N
36°N
35°N
34°N
33°N
32°N
31°N
30°N
124°W
123°W
122°W
121°W
120°W
119°W
118°W
117°W
0.064
0.056
0.048
0.040
0.032
0.024
0.016
0.008
0.000

Monterey Bay's latest trick: turning turquoise

The water in the Monterey Bay, including off Marina State Beach, has been a turquoise color in the past few days because of the presence of coccolithophores, a single-celled phytoplankton that develops scales that reflect the sun. (Vern Fisher - Monterey Herald)

32°N

The map image disp
diatom Pseudo-nitzs
per liter. A value of 0
nitzschia blooms in that pixel.



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NSF RAPID OCE1251573

Historical Data & Model Development

NOAA MERHAB Award (NA04NOS4780239)
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Data Access

Southern California Coastal Ocean Observing System
Central and Northern California Ocean Observing Systems
California Harmful Algal Bloom Monitoring and Alert Network (Cal-HABMAP)